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Vol. XVII, Part II

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ORIGINAL ARTICLES

A STUDY ON THE EFFECT OF CULTURAL FACTORS IN TRANSPLANT PADDY ON THE BEHAVIOUR OF SOME PLANT CHARACTERS INFLUENCING THE YIELD

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(With one text-figure)

PRINCIPALLY there are two methods of paddy cultivation which are practised all over the paddy growing tracts in the world. One of them is sowing of seeds directly in the field by broadcasting and the other is transplanting of seedlings which are raised in nurseries. In Bengal the former method is practised for particular classes of paddy (highland and lowland *Aus* and long stemmed paddy) depending on particular situations of the field. The cultivation of the main bulk of the paddy crop of Bengal is done on semi-low land.

A detailed analysis brings out that the important cultural factors which come into play in the transplant method of cultivation are: (i) Age of seedling at the time of transplantation, (ii) Date of transplantation, (iii) distance between transplanted seedlings, (iv) Number of seedlings transplanted per hole in the field, and (v) Treatment of soil both in the seed-bed and transplant-field.

The object of the present experiment has been to find as to how or to what extent variations in a few of the cultural factors impinge on the various yield-contributing characters of the rice plant to produce a significant impression.

MATERIAL AND METHOD

The experiment was undertaken with a view to study the effects of three cultural factors, namely, (i) strains of winter rice of varying duration of life, (ii) varying number of seedlings planted per hole, and (iii) varying degrees of spacing between holes, on the final expression of the following plant characters: (1) Number of fertile tillers per plant, (2) Number of sterile tillers per plant, (3) Height of the plant, (4) Length of panicle, (5) Extent of exertion of panicle, (6) Total number of spikelets (or grains) per panicle, (7) Ratio of full spikelets to unfilled spikelets per panicle, (8) Weight of 100 grains.

Variants under the three cultural factors were as follows:

I. Rice strains:

(1) *Latisal* (span of life, 135 days)*

(2) *Tilakkachari* (span of life, 150 days)*

II. Number of seedlings planted per hole:

(1) Single

(2) Local (3 to 4)†

III. Spacings:

(1) 6 inches (15·24 cm.)

(2) 9 ,, (22·86 c.m.)

(3) 12 ,, (30·48 cm.)

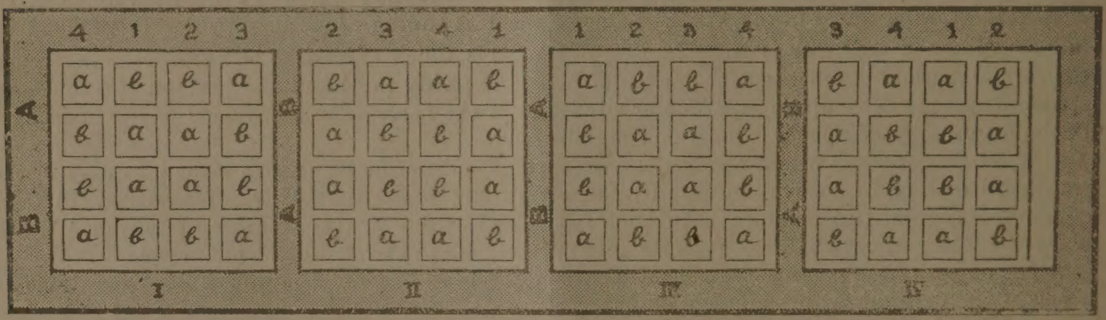
(4) 15 ,, (38·10 cm.)

*Including nursery life of 35 days.

†The latter practice is in vogue among the local cultivators and has therefore been designated in the paper as 'Local'.

Taking these eight factorial variants in combination there were 16 (or $2 \times 2 \times 4$) different treatments. Each of these treatments was replicated four times in four blocks giving a total of 64 unit plots. The area of each unit plot was 81 sq. ft. (9 ft. $\times$ 9 ft.) with 2 ft. wide alleys running between them. The experiment was laid out on a plot of land in a semi-low ravine having clay loam soil as is typical of the transplant-*Aman* rice lands of Madhupur jungle tract in the district of Dacca. The selected plot was remarkably uniform in fertility as was ascertained from the previous observations of crop performance on it.

The design adopted for the experiment is one of the split plot type with strip treatments. There are four different plot sizes: (1) Seedling treatment plots in horizontal strips, (2) Spacing treatment plots in columns, (3) Seedling $\times$ spacing treatment plots consisting of half columns, and (4) Ultimate sub-plots for varieties. The layout of the experiment is shown in Fig. 1.



A = 1 Seedling
B = 3-4 Seedlings.

1 = 6 in.
2 = 9 in.
3 = 12 in.
4 = 15 in.

a = *Latisal*
b = *Tilakkachari*

Area of sub-plot = 9 ft. $\times$ 9 ft.
Footpath round the sub-plot = 2 ft.

FIG. 1. Diagrammatic plan of the experiment.

Seeds of both the varieties were sown in seed-beds on the 16th June and seedlings were transplanted on the 21st July, their age at that time being five weeks.

When the plants were almost mature a row of marginal plants was rejected from all the sub-plots and among the remaining plants in each 20* were labelled at random for making observations on different characters. The position of each of these 20 selected plants in each sub-plot was determined with the help of Tippet's random number series.

The following observations were recorded in the field on the 20 labelled plants and the average per plot was calculated from these 20 observations.

(i) Number of fertile tillers in each plant (i.e. in each hole).
(ii) Number of sterile† tillers in each plant (i.e. in each hole).
(iii) Height of the plant in centimetres from the ground level to the tip of the flag-leaf on the main (tallest) tiller.
(iv) Length of panicle measured in centimetres on the main (tallest) tiller from the lowermost node of the rachis to the tip of the panicle.
(v) Extent of exertion measured in centimetres on the main (tallest) tiller (from the juncture of the flag leaf to the lowermost node of the rachis).
(vi) Number of spikelets per panicle on the main (tallest) tiller.

*In the experiment different numbers of plants have been put in a hole and, as such, it would be more correct to designate "a plant" as "plant in a hole". But for the sake of convenience we have, on most occasions, stated in terms of plants rather than plant-holes, although we have meant the latter unless of course specifically mentioned.

†Tillers that are produced quite late in the life of a plant do not bear ears and have therefore been termed as sterile.

After the above observations were recorded these 20 plants were allowed to attain full maturity in the field and thereafter were harvested for further study in the laboratory and for weighment of the final produce of grain and straw. To prevent any loss of grain by shattering necessary precautions were taken by enclosing the ears of these plants (unsevered from the straw) in small paper bags at the time of harvesting.

The following observations on the grain were taken in the laboratory.

(i) The length, breadth and thickness of 10 grains taken at random from each bag (i.e. from each of the 20 labelled plants) were measured in millimetres with screw-micrometre. The average length, breadth and thickness of grain for each plant were calculated from the measurements of 10 grains of a plant; and from 20 different measurements so obtained, each of length, breadth and thickness, the plot averages were calculated. The product of these three dimensions gave the volume of grain for the plot.

(ii) Weight of 100 grains: Weights were recorded of 100 full grains in the ten random lots, taken from each of the 64 bags containing the grains of all the 20 plants from a plot. An idea of the average weight of a unit number of grains in each treatment could be had from these weights.

STATISTICAL ANALYSIS OF DATA AND DISCUSSION OF RESULTS

The analyses of variances for all the characters studied are given in Table I.

TABLE I

Analyses of variances

Sources of variance		Degrees of freedom	VARIANCES								
			(i) No. of fertile tillers per plnat	(ii) No. of sterile tillers per plant	(iii) Height of plant	(iv) Length of panicle	(v) Extent of exertion	(vi) No. of full spikelets per panicle	(vii) Ratio of full to unfilled spikelets per panicle	(viii) Weight of 100 grains	(ix) Volume of grain
Block		3	2·19	0·49	8·18	16·17	1·28	189·54	2·98	0·01	3·20
No. of seedling		1	4·17	0·01	109·46	22·66	0·46	2278·04†	12·25	0·00	4·29
Error		3	0·49	0·31	104·96	20·78	1·16	40·00	1·58	0·01	34·47
Spacing	Linear	1	1069·64†	5·82†	151·14†	12·48†	2·34	10798·81†	0·60	0·002	0·24
	Quadratic	1	7·45	0·00	3·85	5·55‡	0·02	398·85	0·02	0·00	0·12
	Cubic	1	1·40	0·03	158·65†	1·07	0·04	305·59	2·31	0·005	1·51
Error		9	2·21	0·54	12·80	0·98	0·76	157·25	5·69	0·01	18·88
Seedling × Spacing		3	5·76†	0·44†	2·37	3·30	0·53	151·73	5·70	0·00	6·16
Error		9	0·37	0·04	8·90	1·24	1·50	307·70	2·91	0·0033	10·30
Variety		1	78·36†	0·75	3890·64†	6·02	123·88†	4297·05†	149·51†	1·33†	2109·45†
Variety × Seedling		1	3·44	0·02	3·59	16·76‡	0·94	18·99	0·00	0·00	18·83
Variety × Spacing		3	5·24†	0·06	3·40	1·39	0·69	41·60	4·29	0·00	6·11
Variety × Seedling × Spacing		3	1·07	0·03	9·02	0·52	2·48	57·24	10·58	0·00	12·74
Error		24	1·06	0·27	12·82	3·74	0·91	235·01	5·14	0·01	17·02
Total		63									

†Significant at 1 per cent level
‡Significant at 5 per cent level

(i) *Number of fertile tillers per plant*

This is perhaps the most important of the factors which make up the yield of the plant. The primary results are shown in Table II and significant interactions in Tables III and IV.

TABLE II

Average number of fertile tillers per plant

No. of seedling	No. of fertile tillers	Spacing	No. of fertile tillers	Variety	No. of fertile tillers
Single	9·78	6 in.	4·96	*Latisal.*	11·14
Local	10·29	9 in.	7·67	*Tilakkachari.*	8·93
		12 in.	11·72		
		15 in	15·80		
Mean	10·04		10·04		10·04
S.E.	0·12		0·37		0·18
C.D. at 5 per cent	0·56		1·19		0·53

TABLE III

Number of seedling × spacing (average number of fertile tillers per plant)

No. of seedling	Spacing				
	6 in.	9 in.	12 in.	15 in.	*Mean*
Single	5·00	7·88	11·58	14·67	9·78
Local	4·92	7·46	11·87	16·93	10·29
Mean	4·96	7·67	11·72	15·80	10·04

S.E.=0·22 *C.D.* at 5 per cent=0·69

TABLE IV

Variety × spacing (average number of fertile tillers per plant)

Variety	Spacing				
	6 in.	9 in.	12 in.	15 in.	*Mean*
Latisal	5·49	8·39	13·12	17·56	11·14
Tilakkachari	4·43	6·94	10·33	14·03	8·93
Mean	4·96	7·67	11·72	15·80	10·04

S.E.=0·36 *C.D.* at 5 per cent=1·06

Number of seedling. This factor has got no significant effect on the number of fertile tillers per plant. Table II shows that as was reasonably expected the number of fertile tillers in the local method of planting (3 or 4 plants) is slightly greater than that in the 'single' (one plant). If, however, the tiller per plant (not per hole) is compared in both the cases, we find that 'single' which produces 9·78 tillers is much better than 'local' producing nearly 2·91 tillers per plant. Our results concur with those of Jack [1921], Calvo [1927] and Haigh [1938].

Spacing. Number of fertile tillers per plant varies directly with spacing, statistically, 15 in.> 12 in.> 9 in.> 6 in. This decrease in tiller-number with the decrease in spacing is apparently the result of keen competition between adjacent plants for air, light, soil nutrients, etc., due to crowding. Therefore a greater distance between plant holes provides a more congenial environment for the better growth and development of the plant as partly reflected in the production of a large number of tillers.

The relation between spacing and the number of fertile tiller per plant as well as per acre is shown in Table V.

TABLE V

The relation between spacing and the number of fertile tillers per plant

Spacing	No. of tillers per plant	Ratio	Theoretical No. of plant holes per acre	Ratio	Theoretical No. of tillers per acre	Ratio
6 in.	4·96	1·00	174240	1·00	864230·40	1·00
9 in.	7·67	1·55	77440	0·44	593964·80	0·68
12 in.	11·72	2·37	43560	0·25	510523·20	0·59
15 in.	15·80	3·19	27878	0·16	440472·40	0·51

It may be seen from Table V that if we take 6 in. of spacing as our standard there is, for an increase of every three inches over it up to 15 in., a corresponding increase in the number of fertile tillers in the order of 1·00 : 1·55 : 2·37 : 3·19. But the number of plant holes per acre commencing from 6 in. upwards being in the descending order of magnitude as 1·00 : 0·44 : 0·25 : 0·16, the total number of fertile tillers per plot also shows correspondingly a similar trend of decrease. It will be discussed hereafter if this fall in the number of fertile tillers per acre has any significant bearing on yield.

Variety. Figures in Table II clearly show that *Latisal* produces a greater number of fertile tillers than *Tilakkachari.* From this one may naturally assume that *Latisal* was a better yielder of the two. But this is not so. From the point of yield they were significantly at par. The factors responsible for this levelling up effect will be discussed later in this paper.

Interactions. It is seen from the above tables that the combination of local method of planting with 15 in. spacing in one case and that of *Latisal* with 15 in. spacing in the other give the maximum number of fertile tillers.

(ii) *Number of sterile tillers per plant*

With regard to this character only an interactional effect between the number of seedling and spacing is significant, but since none of the primary effects is significant no importance can be attached to the observed interaction.

(iii) *Height of plant*

The primary effects are shown in Table VI.

TABLE VI

Average height of plant in centimetres

No. of seedling	Height	Spacing	Height	Variety	Height
Single	131·36	6 in.	135·63	*Latisal*	124·87
Local	133·98	9 in.	131·13	*Tilakkachari*	140·46
		12 in.	133·71		
		15 in.	130·19		
Mean	132·67		132·67		132·67
S.E.	1·81		0·89		0·63
C.D. at 5 per cent	8·15		2·86		1·85

Number of seedling. The plant in the 'local' is taller than in the other method of planting, the difference between the two being, however, too small to be taken into consideration.

Spacing. There is a definite tendency of the plants decreasing in height with the increase in spacing. The two intermediate spacings, i.e. 9 in., and 12 in. are, however, at par from the point of significance.

Variety. There is a great difference between the two varieties, *Tilakkachari* being much taller than *Latisal.*

Interaction. None of the interactions is significant.

(iv) *Length of panicle*

This is an important factor contributing towards the yield per tiller since the number of spikelets on a panicle depends on the length of the latter. It is only in a longer panicle that a larger number of branches and a larger number of spikelets can be accommodated.

The primary effects and the significant interaction are shown in the Tables VII and VIII respectively.

TABLE VII

Average length of panicle (in cm.)

No. of seedling	Length of panicle	Spacing	Length of panicle	Variety	Length of panicl
Single	25·16	6 in.	23·62	*Latisal*	24·87
Local	23·97	9 in.	24·83	*Tilakkachari*	24·26
		12 in.	24·88		
		15 in.	24·92		
Mean	24·56		24·56		24·56
S.E.	0·81		0·25		0·34
C. D. at 5 per cent	3·63		0·79		1·00

TABLE VIII

Number of seedling × variety (average length of panicle in cm.)

Variety	No. of seedling		*Mean*
	Single	Local	
Latisal	24·95	24·79	24·87
Tilakkachari	25·36	23·15	24·26
Mean	25·16	23·97	24·56

S.E.=0·48 *C.D.* at 5 per cent=1·41

Number of seedling. The effect of this factor cannot be regarded as sufficient from the statistical point of view.

Spacing. The length of panicle gradually increases with the increase in the distance between adjacent seedlings, 6 in. producing the shortest and 15 in. the longest inflorescence. The difference between 6 in. and each of the other three spacings is significant but there is nothing to choose between 9 in., 12 in. and 15 in. Haigh [1938] obtained somewhat similar results with his three-plant treatments only. It is interesting to note that as compared to the vegetative portion of the axis of the plant (Table VI) the reproductive portion (rachis) is affected in a reverse way by wider spacing so far as the length is concerned.

Variety. *Latisal* appears to be slightly superior to the other variety, although the difference is not significant.

Interactions. With regard to the number of seedling × variety the longest panicle is produced in *Tilakkachari* 'single' and shortest in *Tilakkachari* 'local'.

(v) *Extent of exertion*

The primary effects are shown in Table IX.

TABLE IX

Average extent of exertion (in cm.)

No. of seedling	Exertion	Spacing	Exertion	Variety	Exertion
Single	0·06	6 in.	0·39	*Latisal* . .	1·54
Local	0·23	9 in.	0·22	*Tilakkachari* .	1·24
		12 in.	0·11		
		15 in.	0·14		
Mean	0·15		0·15		0·15
S.E.	0·19		0·15		0·17
C.D. at 5 per cent. . .	0·86		0·49		0·49

Number of seedling. The exertion is slightly more in the case of the 'Local' than in the other, although the difference is not significant.

Spacing. There is nothing to choose between the four different spacings.

Variety. This is the only factor which produces significant effect on the character in question. The extent of exertion is 1·54 cm. in *Latisal* and —1·24 cm. in *Tilakkachari*. The panicle in the latter is partly enclosed by the flag leaf and thereby gives a *minus* value to its measurement.

Interactions. None of the interactions is significant.

(vi) *Number of full spikelets per panicle.*

This is a very important factor contributing towards the yield per tiller.

The primary effects are shown in Table X.

TABLE X

Average number of full spikelets per panicle

No. of seedling	No. of spikelets	Spacing	No. of spikelets	Variety	No. of spikelets
Single	139·26	6 in.	112·39	*Latisal* . .	125·10
Local	127·33	9 in.	132·91	*Tilakkachari* .	141·49
		12 in.	138·67		
		15 in.	149·19		
Mean	133·29		133·29		133·29
S.E.	1·12		3·14		2·70
C.D. at 5 per cent . .	5·03		10·03		7·89

Number of seedling. This factor has got a profound influence on the character in question, the 'single' being significantly better than the other.

Spacing. There is a progressive increase in the number of full spikelets with the increase in spacing, 15 in. giving the maximum followed by 12 in., 9 in. and 6 in. in that order. The first one is significantly superior to all other; 12 in. and 9 in. are both better than 6 in. but they themselves are at par. These results concur with those of Haigh's [1938] three-plant treatments only and not with the others. Hector's [1920-21] findings are also more or less similar to ours.

Variety. The results obtained with regard to the effect of variety shown in Table X appear somewhat peculiar if a comparison is made of these with the results obtained for the length of panicle. Though there is no significant difference between the lengths of panicle of the two varieties, the number of full spikelets is significantly more in *Tilakkachari.* This is apparently due to the presence of a greater number of branches or a closer setting of the spikelets or both in the panicle of *Tilakkachari* than that of *Latisal.*

Interactions. None of the interactions is significant.

(vii) *Ratio of full to unfilled spikelets per panicle*

The primary effects are shown in Table XI.

TABLE XI

Average ratio of full to unfilled spikelets per panicle

No. of seedling	Ratio	Spacing	Ratio	Variety	Ratio
Single	6·31	6 in.	6·07	*Latisal* . .	7·40
Local	5·43	9 in.	5·68	*Tilakkachari* .	4·34
		12 in.	6·10		
		15 in.	5·64		
Mean	5·87		5·87		5·87
S.E.	0·22		0·60		0·40
C.D. at 5 per cent . .	1·00		1·91		1·17

Number of seedling. The effects of different planting methods are not sufficient to stand a statistical comparison.

Spacing. The different spacings also do not influence the character in question significantly.

Variety. This is the only factor producing a significant effect on the character, which is more in *Latisal* than in *Tilakkachari.* This is a varietal character very little affected by the two cultural factors.

Interactions. None of the interactions is significant.

(viii) *Weight of 100 grains*

The primary effects are shown in Table XII.

TABLE XII

Average weight of 100 grains (in gm.)

No. of seedlings	Weight	Spacing	Weight	Variety	Weight
Single	2·95	6 in.	2·93	*Latisal* . .	2·79
Local	2·93	9 in.	2·92	*Tilakkachari* .	3·08
		12 in.	2·95		
		15 in.	2·94		
Mean	2·94		2·94		2·94
S.E.	0·02		0·02		0·02
C.D. at 5 per cent . .	0·08		0·08		0·05

Number of seedling. The effects of the two different methods of planting on the character in question are very small and cannot be compared statistically.

Spacing. This factor also has not produced any significant effect on the weight of 100 grains. These results tally with those obtained by Hector [1920-21].

Variety. Varietal effects are however prominent in that the grains of *Tilakkachari* are significantly heavier than that of *Latisal.* This is a varietal character and is very little influenced by the two cultural factors.

Interactions. None of the interactions is significant.

(ix) *Volume of grain*

The primary effects are given in Table XIII.

TABLE XIII

Primary effects

Average volume of grain—length × breadth × thickness—in c. mm.

No. of seedling	Volume	Spacing	Volume	Variety	Volume
Single	61·50	6 in.	61·35	*Latisal* . .	55·50
Local	60·98	9 in.	61·11	*Tilakkachari* .	66·98
		12 in.	61·46		
		15 in.	61·05		
Mean	61·24		61·24		61·24
S.E.	1·04		1·09		0·73
C.D. at 5 per cent . .	4·67		3·47		2·13

Variety. This is the only factor which produces a significant effect on the volume of grains. As may be seen in Table XIII, grains of *Tilakkachari* are much bigger in size than those of *Latisal.* The character is a varietal one and is not significantly affected by the two cultural factors.

(x) *Yield of final produce*

With a view to ascertain as to how far the detailed observations made on the effect of the cultural factors on the yield contributing characters of the plant compare with the final produce, the weights of the 20 plants under observation were recorded for the grain and straw yields.

The analysis of the yield data are given in Table XIV.

TABLE XIV

Analysis of variance of grain and straw yields of 20 plants

Sources of variance	Degrees of freedon	Variance: Grain	Variance: Straw
Block	3	1·06	19·27
No. of seedling	1	7·66	6·28
Error	3	7·02	6·18
Spacing: Linear	1	3883·61*	6453·47*
Spacing: Quadratic	1	11·79	0·00
Spacing: Cubic	1	19·37	113·57
Error	9	4·72	15·53
Spacing × seedling	3	1·48	83·18†
Error	9	1·82	19·82
Variety	1	10·42	2266·81*
Variety × seedling	1	0·21	0·05
Variety × spacing	3	1·96	94·42†
Variety × spacing × seedling	3	0·66	48·75
Error	24	2·81	26·23
Total	63		

*Significant at 1 per cent level
†Significant at 5 per cent level

The most interesting point in the above analysis is the extremely insignificant variance due to blocks. The same feature is also observable in analysis of variance with respect to other plant characters under study. This confirms the fact that the plot selected for the purpose of this investigation was remarkably uniform in constitution and fertility.

It may be seen from Table XIV that in respect of the grain yield, of all the treatments, spacing only has produced significant effects (at 1 per cent level), whereas for the straw not only both spacing and variety are significant at the same level but there is also an interactional effect of the first order between them as well as between spacing and seedling at 5 per cent level each.

Table XV shows the primary effects on the yield of grain and straw.

TABLE XV

Primary effects

Mean yield of grain and straw of 20 plants in oz.

No. of seedling	Yield		Spacing	Yield		Variety	Yield	
	Grain	Straw		Grain	Straw		Grain	Straw
Single	16·87	26·34	6 in.	6·75	13·78	*Latisal*	16·12	20·71
Local	16·18	26·97	9 in.	11·88	20·37	*Tilakkachari*	16·93	32·61
			12 in.	20·32	32·92			
			15 in.	27·16	39·54			
Mean	16·53	26·65		16·53	26·65		16·53	26·65
S.E.	0·46	0·44		0·54	0·98		0·30	0·91
C.D. at 5 per cent	2·06	1·97		1·72	3·13		0·87	2·65

Number of seedling. The results show that in our experiment the treatment 'No. of seedlings' could not at all influence the yield of grain or straw. Thus our observations on this point are at variance with those of Haigh [1938].

Variety. There is some difference in grain yields between *Latisal* (early) and *Tilakkachari* (late) in favour of the latter but it cannot be established statistically, whereas for straw yields the difference is marked.

Spacing. The four spacing treatments, as will be seen from Table XV, have all produced definite effects on both grain and straw yields. Statistically they are in the order of 15 in.> 12 in.> 9 in.> 6 in.

These results are in agreement with those of various other investigators who have worked elsewhere on this point. Some of these workers have also asserted that although wider spacing is beneficial so far as yield per plant is concerned there is a limit to the spacing which can be utilized by the plants to their advantage. Perhaps it is true, but in our experiment the highest yield per plant has been obtained with 15 in. (38·10 cm.) which is the maximum spacing considered. It is therefore not possible to state whether the yield can be increased further or not by increasing the spacing beyond 15 in.

The average yields of grain and straw per plant (per hole) in this experiment which can be calculated from the figures in Table XV are given below:

	Grain (oz.)	Straw (oz.)
6 in.	0·34	0·69
9 in.	0·59	1·02
12 in.	1·01	1·65
15 in.	1·35	1·98

The above figures show that the widest spacing is the beat, both for the yields of grain and straw per plant. Though the yield per plant increases with the increase in spacing, the number of plants per unit area gets less and less, and, since this decrease is in a greater proportion than the increase in yield per plant, the total yield of the area falls. This feature is shown in Table XVI, wherein the yield per acre is calculated by multiplying the yield of an individual plant (hole) by the theoretical number of plants (holes) per acre. It will be seen that the order of merit is exactly reversed, the widest spacing giving the poorest yield per acre and the closest spacing the best.

TABLE XVI

The number of plant and yield per acre

Spacing	Theoretial No. of plants per acre	Yield per plant in oz.		Theoretial yield per acre in oz.	
		Grain	Straw	Grain	Straw
6 in.	174240	0·34	0·69	59241·60	120225·60
9 in.	77440	0·59	1·02	45689·60	78988·80
12 in.	43560	1·01	1·65	43995·60	71874·00
15 in.	27878	1·35	1·98	37635·30	55198·44

It is seen that the number of plants per acre is of very great importance for the determination of yield per acre. With wider spacing the yield of individual plants definitely increases, and, this is due largely to the production of greater number of tillers and to some extent to the production of greater number of grains per panicle. But the fall in the number of plants per acre is not compensated by the increase in yield per plant. Our results are in agreement with those obtained by Ramiah [1937] and Haigh [1938]. Chakravarty *et al.* [1936] working with plot yields only also arrived at similar conclusions.

Of the two varieties, it was first thought that *Latisal* would prove to be a better yielder since it produces a significantly greater number of fertile tillers. But Table XV shows that it is actually not so. This anomaly could be explained by the results obtained in the case of 'number of full spikelets per panicle' and 'weight of unit number of grains'. It may be seen that the number of grains produced per panicle as well as the weight of unit number of grains in *Latisal* are significantly less than in the other and, as such, the initial advantage gained by the former on account of its production of more fertile tillers is completely lost. Haigh [1938] claims that the number of tillers matured is the limiting factor in the determination of the yield per plant and that the fluctuations in the factors which made up the yield per tiller, viz. number of grains per tiller and weight of individual grains are not sufficient to upset the influence of tiller number. The results obtained by us do not support such a claim.

Interactions. The significant interactions of the first order are given in the Tables XVII and XVIII.

TABLE XVII

Spacing × Seedling

Mean yield of straw of 20 plants per plot in oz.

No. of seedling	Spacing				
	6 in.	9 in.	12 in.	15 in.	*Mean*
Single	14·76	21·37	33·42	35·83	26·34
Local	12·81	19·37	32·44	43·26	26·97
Mean	13·79	20·37	32·93	39·54	26·66
S.E.=1·57					
C.D. at 5 per cent . .	5·01				

TABLE XVIII

Variety × Spacing

Mean yield of straw of 20 plants per plot in oz.

Variety	Spacing				
	6 in.	9 in.	12 in.	15 in.	*Mean*
Latisal	9·74	16·61	25·63	30·85	20·71
Tilakkachari	17·84	24·14	40·23	48·22	32·61
Mean	13·79	20·37	32·93	39·54	26·66
S.E.=1·81					
C.D. at 5 per cent	5·27				

SUMMARY

An experiment was conducted with two varieties of paddy, *Latisal* (early) and *Tilakkachari* (late), to study the effects of two cultural factors, viz. different numbers of seedling per hole, and different spacing between seedlings on some characters of agricultural importance. There were two different numbers of seedlings, single and local (3—4), and four different spacings 6 in., 9 in., 12 in., 15 in. The results obtained for different characters are summarized below :

(i) Number of fertile tillers per plant. The number of seedlings has no effect on this character. 15 in. spacing produces the highest number of fertile tillers followed by 12 in., 9 in. and 6 in. respectively: *Latisal* produces more fertile tillers than the other variety.

(ii) Number of sterile tillers. No factor, not even varieties, has any effect on the number of sterile tillers.

(iii) Height of plant. None of the cultural factors has any appreciable effect on the height of plant. Plants in *Tilakkachari* are, however, taller.

(iv) Length of panicle. The widest spacing 15 in. produces the longest panicle followed by 12 in., 9 in. and 6 in. respectively. There is no significant difference within the last three. There is no differential effect of the number of seedlings nor of the varieties under observation on this character.

(v) Extent of exertion of panicle. *Latisal* is more exerted than the other variety. The character is not affected by the two cultural factors.

(vi) Number of full spikelets per panicle. The number of full spikelets is more in the 'single' than in 'local' planting. There is a gradual increase in the number of this per panicle with the increase in spacing. Of the two varieties, *Tilakkachari* has a larger number of full spikelets per panicle.

(vii) Ratio of full spikelets to unfilled spikelets. This ratio is more in *Latisal*. The two cultural factors have no appreciable effect on it.

(viii) Weight of grain. The weight of grain in *Tilakkachari* is more than in *Latisal*. The cultural factors do not affect the character appreciably.

(ix) Volume of grain. *Tilakkachari* has a larger volume of grain than *Latisal*. The character remains unaffected by the cultural factors.

(x) Yield of final produce. Of the three factors under consideration, spacing only has produced a marked effect on both grain and straw yields. Significantly the four spacings are in the order 15 in.> 12 in.> 9 in.> 6 in. These differential effects could only be established for individual plant yields but when the yield per unit area is considered the respective position of the series of spacings gets reversed. In the case of straw, however, 'Variety' has also been equally effective ; for the two varieties under observation, *Tilakkachari* > *Latisal*.

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A NEW SIMPLE METHOD OF ESTIMATING THE MOISTURE CONTENT OF SOIL *IN SITU*

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(With four text-figures)

AN accurate estimation of soil moisture is of great importance in agricultural practice as well as in many problems of soil physics. There are serveral methods which at present are in general use for this purpose; but almost all of them are either laborious and slow or are not sufficiently reliable. The method most commonly used consists in taking a sample of soil from the field and driving out the moisture in a steam oven. The loss of weight during the drying process gives the weight of the moisture content which is expressed as a percentage of the weight of the dry soil. This method although fairly accurate is laborious and very slow, as it takes several days to drive out the moisture completely from the soil sample. Various other methods have been tried for estimating the soil moisture more quickly. These may generally be classified as follows:

(i) *Electrical conductivity method.* This method first tried by Whitney, Milton, Gardner and Briggs [1897] uses the electrical conductivity of the soil as an index of soil moisture. The salt content of the soil, however, introduces a considerable error in this method. A modification of the above method using multiple electrodes has been attempted by McCorkle [1931], but the results are reported not to have proved entirely satisfactory.

(ii) *The Dielectric Constant method.* In this method, due to Fletcher [1939], the soil forms the dielectric of a special condenser buried in the ground and the dielectric constant of the soil which varies with the moisture content is taken as an index of soil moisture. Readings by this method are, however, affected by salt concentration and the colloid content of the soil.

(iii) *Tensiometers.* These instruments measure the capillary tension of the soil water. Richards, Russell and Neal [1937], and Richards and Gardner [1936] have investigated the relationship between the water content of soil and its capillary tension. The basic form of this instrument consists of a porous candle filled with water and connected to a mercury manometer. The porous candle is placed in the soil and water moves into or out of the candle depending upon the moisture content (capillary tension) of the soil surrounding the porous candle. This movement of water is indicated by the change in the mercury level in the manometer. The method, however, has proved more useful for the purpose of studying the movement of water in soil than for the determination of its moisture content. This is mainly due to the fact that the instrument requires some time to get into equilibrium with the surrounding soil and hence there is a considerable hysteresis effect in the instrument. It cannot also be used for soil moisture contents below the moisture equivalent, when the capillary tension of the soil-water exceeds one atmosphere and the instrument suffers from the formation of air bubbles which effectively stop the instrument from functioning.

(iv) *Thermal conductivity method.* The variation of heat conductivity of soil with changing moisture content has been reported as early as in 1909 by Patten. It is only recently [1939], however, that a practical method has been proposed by Shaw, Byron and Baver in America utilizing this variation in thermal conductivity as an index of soil moisture. In this method used by Shaw, Byron and Baver the thermal conductivity of the soil is measured with an electrical apparatus based on the Wheatstone bridge principle. An enamelled copper-wire element forming one of the arms of a Wheatstone bridge is buried in the soil and a fixed current (0·4 amperes) is passed through the circuit for one minute. The temperature attained by the copper-wire element at the end of one minute will depend on the thermal conductivity of the soil which in turn will depend on the moisture content, packing and composition of the soil. As the electrical resistance of the copper wire depends on its temperature, the temperature attained by the element at the end of one minute is indicated by the

out-of-balance current in the bridge detector which is a sensitive micro-ammeter. The lower the thermal conductivity of the soil the higher is the temperature attained by this element.

It will be seen that the equipment required for the above method is rather elaborate and requires a sensitive micro-ammeter and a source of constant voltage for the bridge and it is obviously beyond the means of an average Indian farm observatory. The present paper describes a new method based on the same principle but greatly simplified.

The new method and apparatus

In the method of Byron, Shaw and Baver the Wheatstone bridge is used for the measurement of the temperature attained by the copper-wire element at the end of one minute. In the method developed by the present writer, this indirect method of temperature measurement is eliminated by making use of the special type of thermometer which is generally used for the measurement of soil temperature at different depths. These thermometers have very long stems so that when the bulb of the instrument is buried in the ground the scale is above the ground surface. Instruments of this type are available for use at different depths up to 2 ft. below ground level.

On the bulb of such a thermometer is wound a heating element consisting of a No. 32 or 30 enamelled or silk covered constant wire, which covers half the bulb of the thermometer. A coating of an insulating material (Durofix was used in the present investigation) is applied over the wire covered portion of the thermometer bulb. This insulates the heating element electrically and, to some extent, thermally from the soil in which the thermometer is placed and also protects the element from moisture. A 6-volt storage battery or a large capacity dry cell battery is used as the source of heating current and is connected to the heating element through a variable resistance, an ammeter and a switch in series. The bulb of the thermometer is then burid in the ground at the desired depth and in good thermal contact with the soil. The measurement is made by passing a fixed current (0·3 amperes was used in the present investigation) through the instrument and recording the time required to raise the temperature of the thermometer bulb by 5°C. The time is recorded in seconds with an ordinary watch or preferably with a stop watch.

Patten [1909] has investigated the thermal conductivity and diffusivity in soils in relation to their moisture content and other factors, viz. packing, composition, etc. He finds that, the packing of the soil remaining the same, its thermal conductivity increases with its moisture content. Now, the thermometer bulb in the above instrument is heated by a fixed current, (therefore at a constant rate) and, as it is the bare half of the thermometer bulb that mainly dissipates heat through the soil, it will be seen that the time required to raise the temperature of the bulb by a fixed amount will vary with the thermal conductivity of the soil. That is, the packing of the soil remaining the same, it will take longer to raise the temperature of the thermometer by the same amount in a wet soil than in a dry one. This is the basic principle of the instrument. Fig. 1 gives a sketch of the instrument.

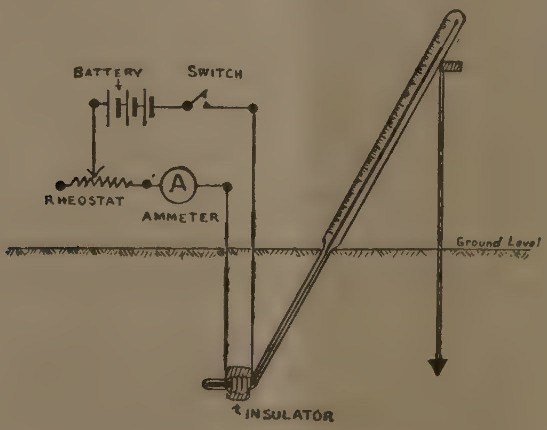

Fig. 1. A sketch of the instrument

The instrument was first tried in the laboratory with Poona Black Cotton soil at different moisture contents. It was, however, not possible to keep the packing of the soil exactly the same at the various moisture contents, but as far as possible, care was taken to see that the soil occupied almost the same volume at each moisture content. After the current was switched on, the readings of the thermometers were taken at intervals of 10 seconds until the temperature increased by 23°C. The results of this experiment are given in Fig. 2. These curves show the effect of moisture content on the thermal conductivity of the Poona Black Cotton soil.

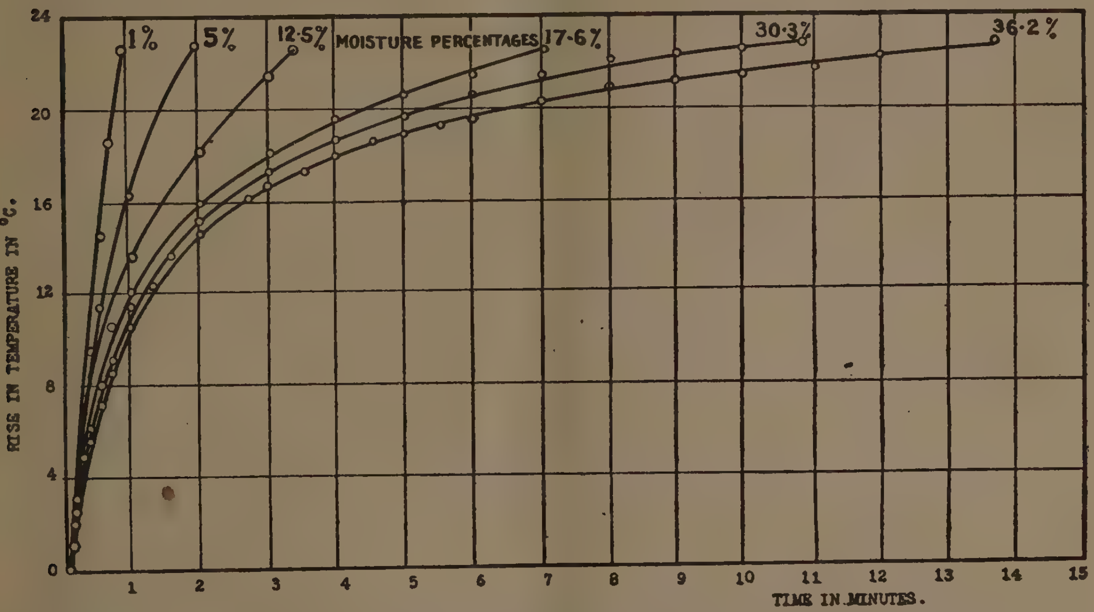

FIG. 2. Temperature—Time curves for Poona Black Cotton soil at various moisture contents with a heating current of 0·7 amperes

The effect of various values of currents has also been studied. Fig. 3 shows the Temperature Time curves for dry Poona Black Cotton soil with different heating currents. It was found that the most suitable value of the heating current depends on

(i) the resistance of the heating element,
(ii) the size of the thermometer bulb, and
(iii) the amount by which the temperature of the thermometer is to be raised.

It is undesirable to use a very high value of current as this will not only reduce the life of the heating element but also will necessitate the use of a large capacity battery. At the same time, it must be remembered that a very low current will reduce the rate of temperature rise of the thermometer and consequently reduce the accuracy with which the time for a definite rise of temperature can be recorded. This is also true of a very high current which will make the rise of temperature too fast for accurate measurement. The current, therefore, should be of such a strength that the rise of temperature should be just fast enough for accurate measurement, when the soil is saturated.

Two instruments of the above type were installed at the Central Agricultural Meteorological Observatory, Poona, at depths of 3 in. and 9 in. below ground surface. A single battery and rheostat were used for both the instruments with a suitable switching arrangement. While installing the instruments, special care was taken that the soil was disturbed as little as possible and that the bulbs of the thermometers were making a good thermal contact with the soil. The readings of the instruments were taken at intervals usually of 3 to 4 days and simultaneously samples of soil were taken

from an adjoining plot from depths at which the instruments were installed. The moisture contents of these samples were determined by the conventional drying and weighing method. The values of

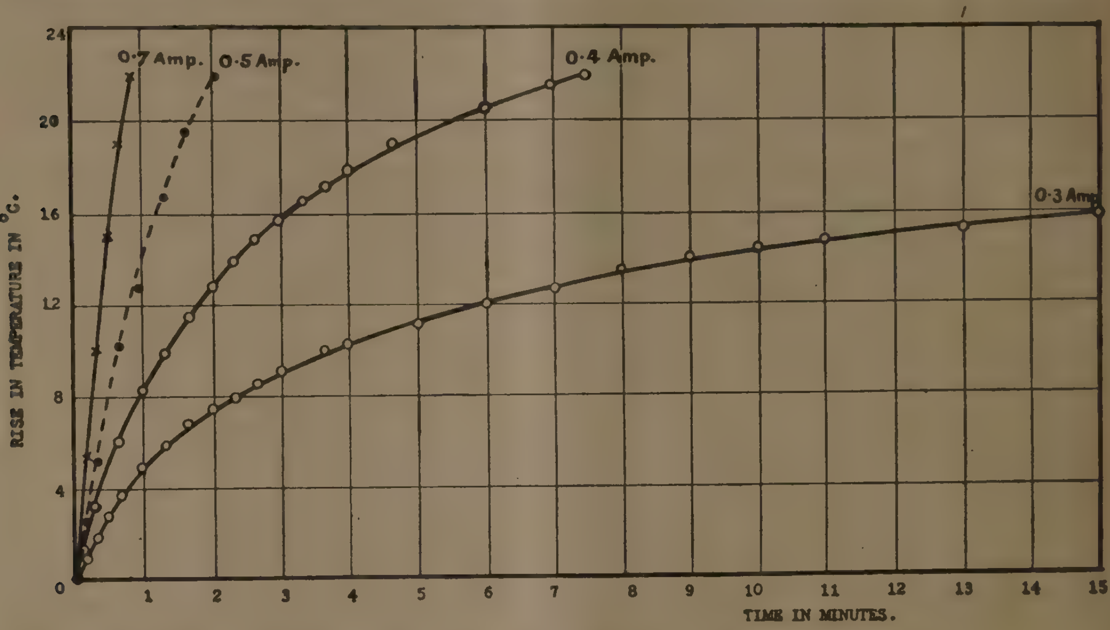

FIG. 3. Temperature—Time curves for dry Poona Black Cotton soil with various heating currents

moisture content thus obtained were plotted against the time 't' in seconds required to raise the temperature of the thermometer by 5°C. Fig. 4 shows the relationship between 't' and moisture percentage for each of the instruments. It is satisfactory to note that almost smooth lines can be fitted through the various points. Whatever scattering of the points is present, is mainly due to errors in judging the exact depth from which the soil samples are taken. This error is especially noticeable in the clear season when the surface layer of the ground has become dry and the moisture content of the soil increases very rapidly with depth.

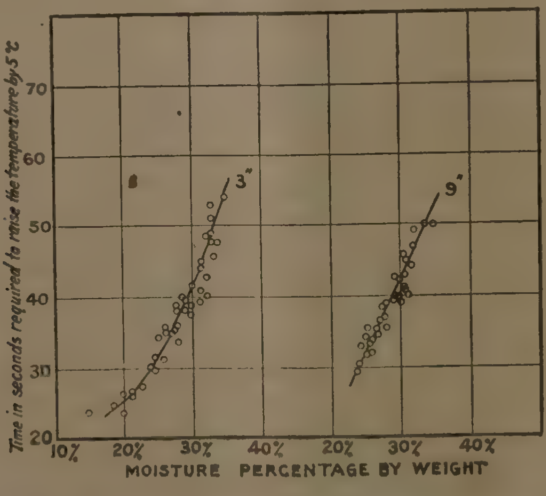

FIG. 4. The relation between 't' and moisture percentage

The regression equations given the relationship between '*t*' (time required to raise the temperature of the thermometer by 5°C. with a current of 0·3 amperes) and '*M*' the moisture percentage of the soil for both the instruments are given below:

3 in. depth—$M = \cdot 86 + \cdot 93t - \cdot 0055t^2$.
9 in. depth—$M = \cdot 51t + 8\cdot 89$.

Once these curves are obtained for each instrument over the normal range of moisture variations under field conditions, the calibration of the instrument is complete. Later, whenever, a determination of the moisture content of the soil is required, it is only necessary to take a reading of the instrument and read off the value of the moisture content immediately from the corresponding calibration curve. The calibration of the instrument takes, if the right season is chosen (the beginning or the end of the rainy season), about 2 or 3 months.

The only major precautions to be taken while using these instruments are

(i) the instrument as well as the soil around its bulb should not be disturbed in any way, and
(ii) a constant current should be used for taking the time readings.

The first is achieved by keeping a separate plot of ground for the instrument, which is not likely to be disturbed; the second is achieved by keeping the battery properly charged or by making periodical adjustments of the rheostat in case a dry cell battery is used. This does not present much difficulty as the current drain from the battery is only 0·3 amperes and the battery is used only for a few minutes once or twice a week.

The main drawbacks of this method are that variations in the packing of the soil particles effect the readings and that it takes rather long to calibrate the instrument, which must be done on the spot where the instrument is installed. But the same limitations would apply to the method of Byron, Shaw and Baver mentioned above. It may be mentioned here that the variations in the packing of the soil particles, which are due to variations of moisture content of the soil itself do not effect the accuracy of this method, as they are taken into account in the process of calibration of the instruments.

Summary

(i) The method described above is an extremely simple one and is especially suitable for experimental farms in India which usually possess thermometers for recording soil temperatures at different depths. By adding a heating element these can easily be adapted for soil moisture measurements without affecting their efficiency as soil thermometers.

(ii) In addition to the great saving in labour and time by the use of this method it may be mentioned that the accuracy of this method is comparable to that of the drying and weighing method. Further work is in progress.

Acknowledgement

In conclusion the writer wishes to thank Dr L. A. Ramdas, Agricultural Meteorologist, under whose guidance this work is progressing. The writer's thanks are also due to Messrs. Dasradha Rama Rao and V. K. Ramabhadran for computing the regression equations given in the paper.

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METHODS AND FACTORS THAT ENABLE A PLANT TO WITHSTAND TRANSPLANTING

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TRANSPLANTING is a three-act operation. It includes digging of a seedling from its growing place, transporting it to a desired place, and planting it there properly so that it may grow efficiently and effectively. Transplanting--though in itself not an essential operation as will be explained later—is of great economic importance and potentiality in modern agriculture. Man has used it as a great and effective weapon in his continuous effort to overcome the limitations nature has imposed upon him in his efforts to grow his food. By transplanting methods, man has overcome the limitations of a short growing season. He has widened his domain for growing his food into areas which ordinarily would not grow some of the produce because of short growing seasons for them. The economic importance of transplanting, therefore, is so great that study to find the factors and methods for successful transplanting is very essential.

The advantages of transplanting centre around the economic factors. Of course, it helps the man to extend his growing season, and also to have plants where he wants them to be. It helps growers to use most economically and effectively the most valuable space in the greenhouse. A grower can take care of his seedlings in flats in the greenhouse in their early stage, more economically and efficiently. He can do so with less labour, with little fertilizer, and he can protect them more fully from diseases and insects while the seedlings are in the greenhouse. It also makes it possible for the grower to save his seed, and so lower the seed cost considerably. During the operation of transplanting, the unavoidable root injury—in fact, a sort of root pruning—stimulates root growth later, and this branching of roots not only helps the plant to set easily and readily, but also helps it to overcome the transplanting shock quickly.

Transplanting, as suggested above, has in itself no advantages. In fact, it has several disadvantages. It calls for extra labour and extra expenses. The injury to roots is unavoidable, and most of the root hairs are destroyed. The skill and technique can be devised and followed that this root loss could be greatly reduced. Above all, transplanting checks growth. This also retards development, and defers fruit production, so reducing early yield, by the reduction of roots and leaves. The check in growth caused [Loomis, 1925] by transplanting alone, is proportional to the duration and extent of the disturbance of root and top balance, which is a balance between the absorption of water by roots, and loss of water vapour through the leaves and stem. Measures and methods can be adopted which can minimize these disadvantageous effects of transplanting, and so it can well contribute to the success of transplanting. To do so, a study into the nature of problems involved in transplanting is very essential.

Plants vary greatly in their ability to be transplanted successfully. Some plants recover more readily from transplanting than others do. Cabbage, beets, and lettuce are some of those that can be easily transplanted. The check in growth in the case of corn, cucumbers, melons, and beans [Thompson, 1939] is so marked and great that unless the plants are very small, they can not be very successfully transplanted. It has further been found [Loomis, 1925] that plants which are readily transplanted are those whose damaged and destroyed roots are speedily replaced by new root growth. This replacement in turn depends upon the ability of the roots retained by the plant to absorb moisture freely, and this further depends upon the fact that these plants have very little, if any, suberin or corky covering on the roots. Those which are hard to transplant are distinctly suberized.

This should suggest that if speedy root growth somehow can be stimulated and increased, and suberization can be either checked or reduced, the possibility of successful transplanting can be greatly increased. The effect of transplanting shock caused by the disturbance in absorption and transpiration balance could also be minimized if somehow transpiration could be reduced, and absorption could be stimulated and increased. As the absorption of water by roots in general

depends upon the absorbing root area, so care and precaution could be devised to cut down the loss of root absorbing area. The control of temperature, humidity while the seedlings are being transported, and the check in transpiration by some waxy spray, or by any other means, would greatly increase the chances for successful transplanting.

As various factors, both environmental and internal which affect recovery from transplanting, all act through their final effect on water supply, so the solution of the problem of having a water supply in the plant, which supply can be held against unavailability, and which can afford a continuous water supply around the roots after setting transplants, will greatly contribute to successful transplanting. The check in growth, which generally varies directly with the quantity and duration of the reduction of water supply, can so be reduced to its minimum.

The check in growth during transplanting also varies directly in proportion to the size of the plant at the time of transplanting. This difficulty can be overcome by managing to have seedlings of proper size and age, at the proper time, and at optimum conditions. The growth of tender, leggy and older plants will be greatly checked by transplanting, while a hardened, normal size, and healthy plant may come out of the transplanting process with the least check in growth.

Seedlings grown in greenhouses, generally under favourable optimum conditions, usually become rather soft, so at the time of transplanting they will find it hard to withstand the hardship of extremes of weather in the new environments. They become more susceptible to injury from cold and hot weather, from wind, and insects. The loss of water would greatly injure such seedlings, and their immunity towards diseases at this stage could be anything but optimum. Therefore, these plants must be hardened.

For successful transplanting, hardening is one of the most important practices, knowledge of which is very important, for it involves one of the most delicate physiological processes and changes in a plant. Plants are hardened to withstand cold as well as heat. Properly hardened plants can withstand effectively desiccation by dry hot winds, as well as by frost. They can withstand whipping. Hardening of the tissue, and formation of cutin on the leaf surface, and other physiological changes are brought about during hardening. They make the plant less susceptible to the attacks of diseases and insects. They also have less physical injury from handling during transplanting.

Hardened plants are more capable of retaining water. They also accumulate a deposit of carbohydrates during the hardening time. These factors in proper combination are more influential in initiating a prompt regeneration of root growth. This, of course, brings about intensive metabolic activities on the part of the root cell, and this increases respiration, accompanied by a higher rate of transpiration. But the increase in water loss thereby is so insignificant, although unavoidable, that it should be overlooked.

Proper hardening is essential for best results. Gradual hardening gives best results, and also helps to avoid overhardening. To keep plants on the dry side is better, as well as an easy method of hardening plants. It is easy to control moisture by withholding irrigation or by a limited application of water. It involves no extra labour operation, and serves to reduce water and labour costs.

Lowering the temperature is another method practised either alone or along with moisture control to harden plants. It is rather difficult to control temperature, and this involves extra labour and care. Unless great precautions are taken, plants might be seriously injured, or a serious check in growth may occur by too low a temperature. Besides, in the case of certain plants, subjection to cold temperature in early stages would greatly increase the danger of bolting. Cabbage, celery, and beets in particular, are very susceptible to such temperature changes. They, if subjected to cold temperatures for about a week, will mostly go prematurely to seed.

Plants can be hardened also by withholding nutrients. This is a starving method. It is not a very desirable practice, for the starved plants later do not do so well. Yellowing of leaves and stem and toughening of tissue is a very characteristic sign of nitrogen deficiency, quite apart from that caused by cold and moisture deficiency. Starved plants are very slow in overcoming a transplanting shock. They are slow to recover. The yield, especially the early yield, is greatly reduced [Crist, 1928].

All plants cannot be hardened. Tender plants such as potato and sweet potato cannot be hardened. Only hardy or semi-hardy plants such as cabbage, cauliflower, celery, beets, and lettuce, the plants usually so treated, can be hardened successfully.

To understand the nature of hardening, a knowledge of the changes that accompany hardening is very useful and necessary. Rosa [1921] sums up these changes as follows : slowing of the rate of growth ; thickening of cuticle and increase in the waxy covering on the leaves ; increase in the percentage of dry matter ; decrease in the transpiration per unit area of leaf ; increase in the quantity of hydrophyllic colloids, especially pentosans ; decrease in the freezable or free water ; increase in the percentage of total sugar ; decrease in starch, and the development of a rather pink red colour, especially in stem, petiole, and leaf veins. The leaves of well-hardened plants are darker green and smaller than those of non-hardened plants of the same age. Hardening brings such changes in proteins as prevent them from precipitating easily. In case of cabbage, increase in amino acids was noticed.

The effect of hardening to establish a morphological trend in the stem is very noticeable especially in hardened tomato plants. This is characterized by an excessive differentiation and maturation of the tissue. This trend [Crist, 1928] involved the leaves and fruits and amounted to a permanent check in general development. The upper part of the plant, which developed subsequent to the period of hardening, had a different morphological trend, and was not affected adversely. The early, but not the total, yield of hardened tomatoes, is greatly diminished. Holding out tomatoes, therefore, is not a very advantageous practice.

The application of nutrient salts previous to setting seedlings in beds [Crist, 1928] did not relieve the check suffered during the hardening process, even though the conductive systen was not impaired, as generally it is not. In the case of cabbage, there was no check in growth of any practical consequence during the temporary limitation of nutrients. So no bad effect may be expected to follow hardening incident to delay in transplanting. This is true also of tomatoes, but with the exception that the hardened part is not rejuvenated. The hardened part is permanently affected, and is characterized by accelerated and increased differentiation and lignification of tissues, which consequently cause reduction in mass of stem and fruit. The growth of the conductive system is, however, not inhibited.

This all brings out the suggestion that on one side, the dependence upon hardened plants is not a desirable practice because preparing tomato plants to survive the rigour of a pre-season environments, imposes a handicap from which they recover so slowly that tender plants set in the field considerably later overtake and surpass them and prove profitable ; on the other hand the time of transplanting in the field must be properly calculated, for any plant can stand a certain definite amount of adverse weather and no more.

To have a healthy, properly hardened plant of a certain age and size, a definite plan should be made in early winter, or still better, in fall. To grow your own seedlings or to buy them is an individual problem, but one which must be settled early. If it is decided to grow your own seedlings, the seed of a desired variety, preferably a certified seed of disease-resistant variety, should be had early. Temporary sash-houses, hot beds, hot-bed-pits, or manure heated beds could be arranged. In greenhouses, proper sized flats are very handy. The date of planting seed depends upon the variety, the time it generally takes to grow a good sized seedling, and the approximate time at which the seedlings are expected to be set in the field.

The disease-free flats and soil should be used, and seed should be treated against diseases. In flats, sterile sand is generally used, so that at pulling time, the root injury may be greatly reduced. The seed bed is well prepared and the seed planted in rows and watered well with water at first and later a properly prepared starter solution to keep the soil moist. If need be, the bed should be covered. Great care should be given to the temperature, moisture, and ventilation. Chilling the plants and overheating should be avoided. Soft plants over watered and lacking ventilation become very susceptible to 'damping off'. To protect seedlings from 'damping off,' and to grow them well, the use of *Sphagnum* moss is very effective and so will be discussed later fully. The use of hydrophyllic colloids of high viscosity, such as methylcellulose, as a seedling growing medium has great potentialities as a protection against 'damping off', root injury, and wilting. A protection

against wilting is a direct measure of successful transplanting. The use of methylcellulose in flat soil, or even in the field, seems to be the answer. To be [Felber, 1944] effective in spring, the treatment should be given in fall. Methylcellulose fibres in soil help to conserve the moisture. Proper choice of the amount of methylcellulose and its viscosity grade, giving due regard to the water-holding capacity of the soil and the prevailing condition of moisture and temperature, the method of methylcellulose soil treatment may possibly be successfully used in orchard and fields. It is inverse to sol-gel transformation of agar and gelatin, a fact which is of great advantage for it to be used as a seedling-growing medium, for it will gel in warm weather, but it acts as a sol at cool temperatures, at transplanting time, and thus will keep the root moist, an optimum condition for new root growth. Methylcellulose used in flat soil will not only make it possible to pull seedlings with the least root injury to them, but also will, when around roots, protect them against drying [Felber and Gardener, 1945]. In culture solutions, methylcellulose decreased the water requirement by about 30 per cent. In rich soil, rich in organic matter, the treatment may cause a slight retardation of growth when the moisture content is high. In sandy soil, however, the growth accelerates. So it can be used advantageously to prevent a detrimental effect of a temporary drought period in delaying growth during transplanting. Its use will further cut down the labour requirements and expenses of artificial methods used to avoid wilting. Its use will help to control erosion and prevent run-off water from sandy soil.

Sphagnum moss has been used as a seedling medium. Its use is a very effective control against 'damping off'. Roots of seedlings are least injured at pulling time. It can be easily blocked or balled over roots before lifting, and thus can give a greater protection to roots. It can be easily obtained. The application of nitrate solution or complete nutrient solution is essential, however, especially after transplanting in the field when *Sphagnum* moss is used [Stoxtemyer, 1943].

Seedlings, when growing thick in transplants and having two of their real leaves grown fully, are generally transplanted into other beds of flats with a greater space to each plant, or they are transplanted into pots, dirt bands, paper boxes, paper bands, wood pots, or veneer bands. With a container to each seedling, it becomes easier to handle and transport the plants, but it becomes so expensive. However, it gives best results. Loomis [1925] in New York, found a 30 per cent gain in seedling transplanted in paper boxes over those directly transplanted into the field without being transplanted into any container. It is a great gain, sufficient to meet the extra expenses of containers and handling them.

The container should be sanitary, and they should be soaked in a fertilizer solution before they are used. Wood or paper material around roots causes a condition that brings about nitrogen deficiency, so the use of extra nitrogen is advisable.

Fertilizers, not only in starter solutions for seedlings, but also in the field, are very essential for successful transplanting ; so is the preparation of soil. Properly cultivated soil, loose and friable, moist and retentive of moisture, with sufficient amounts of organic matter, will make successful transplanting much easier. The use of methylcellulose to increase the moisture retentive qualities of the soil, as mentioned above, could be very beneficial. Proper fertilization also is very essential. The actual amount and quality of fertilizer depends upon the initial fertility of the soil. The relative ratio of potassium, phosphoric acid, and nitrogen can be so manipulated that to start with the application of a fertilizer should encourage root growth rather than top growth. The fertilizer with more potassium and a little nitrogen, either in starter solution, or on the planting line in beds before transplanting properly applied could do the trick. Later application of an extra nitrogen solution as a side dressing after the seedlings have set, would prove greatly beneficial in stimulating the top growth.

The soil should be free of weeds, and care should be taken against insects and diseases. Well-drained soil is necessary.

Before the seedlings are brought to the field, they should be well hardened as described above. They can be given several physical as well as chemical treatments to enable them to withstand transplanting better, which will be discussed below. They should be properly pulled with the least injury to roots. It would be better to lift them up with soil and roots from below with a scraper with the least disturbance to the latter. The soil will also protect the roots from drying while being transported to the field. The use of containers, blocking, and 'pricked' plants is a great help in protecting

plants from drying. Plants should be shaded, covered with wet sacking, and the roots should be kept moist. Placing the containers and flats on a flat wagon floor and transporting them to the field would give the least disturbance to the roots, and so the least root injury. Small and weak plants should be discarded.

If the seedlings have to be bought, not only should they be of the proper size and age, but they should be in an optimum condition, and must be had at a desired time. Handling of seedling and packing is very important. They should be bunched and tied with the roots well protected. They should be placed in baskets or special crates, and should be well ventilated. The use of packages, such as are used for vegetables, has a great scope. Parchment or whole hide packages, used for vegetables, can also be beneficially used for seedling transportation. This material can stand water. Properly used at a right temperature in transportation, they may reduce transpiration greatly, and prevent wilting. They permit the air to pass slightly [Brown, 1928], which keeps respiration going, but which does not increase the water loss, by transpiration greatly. Whale-hide excludes light, but parchment permits light to pass through, and so this may even permit the photosynthesis to go on in the packages. Although there is no experimental work to support the suggestions, if such packages are used and photosynthesis can take place in the package, the seedlings could use the carbon dioxide in the package produced by respiration of the plants, and thus could avoid toxication or break down effect of suboxidation in the tissues of seedlings. It could also at least stabilize the carbohydrate supply in the plants, which later may greatly help the stimulation of the new root growth. Packages of celoglass, vitres, flexglass, waxed paper could be used for experimental work. This work could find out which material would suit better. These all with the exception of whale-hide permit the passage of light.

Pliofilm [Stahl and Vaughn, 1942], a nitrogen synthetic plastic, may turn out to be of great use for packages for seedlings. It is a moisture-proof substance, but permits the diffusion of carbon dioxide. The disease side of the problem should be studied and if no danger is found, the use of a little water around the roots in packages can be a great guarantee against root drying.

Not only the study into the practicability of the use of such material for transportation of seedlings would help to find a way of transporting seedlings with the least risk of drying but the study of the use of several waxy or oily materials to be used as a spray on seedlings to check transpiration temporarily would also help a great deal. Pliofilm may prove of great value in this respect too. It will not permit moisture to escape, and will permit diffusion of carbon dioxide. It may do away with transpiration, an unavoidable but necessary evil to plants.

Time and weather conditions also help greatly in successful transplanting. Early in the morning or late in the afternoon, in early spring or late fall in a windless, calm day, or when it is cloudy, or the temperature is low and humidity high, the transpiration is low and there is less chance of wilting, and so a greater time is available for the roots to grow and start working before wilting can take place. Planting in furrows will help against wind.

A hole of proper dimensions for the roots, and a stem set a little lower than its previous level would help successful transplanting. A firm and gentle pressing of dirt on roots to avoid air pockets is of great help. Watering before the hole is closed is of great benefit. Direct water to roots at the time of transplanting [Nuckols, 1931] greatly increases the chances of survival and also increases the yield considerably. It is expensive, of course. A substitute for this method, yet not so expensive, is puddling of seedling roots in a watery mud. The use of special fertilizer, hormone, growth promoting substances, and methylcellulose in this mud may prove of great benefit. A precaution should be taken, however, against letting this mud dry on roots before they are set in the field. The soil around the roots in the hole should be moist, too. The starter solution of KNO_3 and $(NH_4)_2SO_4$ or potassium and phosphoric acid used in a suitable combination as the conditions warrant, in mud, may be of great help in successful transplanting. Putting dry dirt around the stem near the surface is advisable. Sawdust can be used for mulching around the stem near the surface with great benefit, but it may cause a nitrogen deficiency which can be overcome by the application of extra nitrogen solution.

Protecting the transplants from bright sunlight and wind is recommended when economically possible, especially for the first couple of days after transplanting.

Pruning of top and roots is practised sometimes. 'Snipping off,' pinching, or even defoliation is practised with the idea of cutting down transpiration. Pruning of damaged and injured roots may be advisable to give a stimulation to root growth, but generally root pruning should be avoided. Pruning of top and roots has been found to decrease the yield [Krause, 1944]. Defoliation or pruning the top may reduce the transpiration and thus facilitate successful trasplanting, but it would also cut down the production of carbohydrates which are much needed for new root growth. It will delay the crop, and may reduce the yield considerable. Pruning of top and roots, however, is practised on celery without too much set back. 'Snipping off' the upper part of the cabbage plant may be practised advantageously when dry weather is a serious factor, and if the growing season is long, for the crop will be late. Pinching back of the main stem of tomatoes will make the fruit setting late, but those of the lateral shoots of a stacked tomato plant would increase the early yield. Defoliation of lettuce plant [Krause, 1944] reduced yield and delayed maturity of head lettuce. The same result was obtained with cauliflower. Even in case of celery, heavily pruned plants yielded less than unpruned plants. Pruning, however, did not effect the length of the petiole. Pruning of celery plants below their eight week limit did not prove to be of any harm, and unpruned onions did not show any advantage over pruned onions.

As far as transpiration is concerned, unpruned plants transpired less per unit area than pruned plants. In general, the rate and amount of root and top growth of cauliflower and celery plants subsequent to pruning were reduced in proportion to the amount of foliage removed. Plant recovery and resumption of root and top growth after transplanting appeared to be directly correlated with the amount of carbohydrate present in the plant after pruning or at the time of transplanting.

The presence of carbohydrate, especially in relation to nitrogen in plants, is another angle, study of which may help greatly in successful transplanting, for it has been found that the relationship of carbohydrates to nitrogen in plants influences a great deal the top and root growth. Although most of the work has been done on fruit twigs, which work is briefly reviewed here with the notion that similar work on vegetables may give similar results.

Goldlewski's [Reid, 1924] work suggests that in the absence of nitrogen, root formation is favoured more than shoot formation. Chandler [1919] found that root growth increased much less than top growth by the addition of nitrates to peaches. Gericke [1922] has found that an abnormally large root development of wheat seedlings in proportion to that of top is primarily associated with deficiency of nitrogen in the subsequent substrate. Dachnowski [1914] working on tomato cuttings, found that cane sugar solution somewhat increased root growth. The knowledge of this fact can be exploited by dipping seedling roots in a proper cane sugar solution before transplanting, or even when they are growing in the flats. The work of Knudson [1916] supports the above view for he found a marked influence of certain sugars on root growth of seedlings in relation to both their extent and their branching. Krause and Kraybil [1918] observed that a decided reduction in the development of root systems of tomato plants accompanied a continued removal of leaves from the top. According to micro-chemical tests, the practice also resulted in a marked decrease in carbohydrates in the stem and decided reduction in vegetative extension.

After the short review of carbohydrate and nitrogen relationships as to root and top growth, we can better appreciate why the defoliation practice in transplanting time is more harmful than beneficial, and also why hardening, besides its other advantages, helps greatly in successful planting by the accumulation of carbohydrates.

The interrelation of material within and without the plant is of great influence on top and root growth. Robbins [1922] found that excised roots of several kinds of seedling would, under sterile conditions, develop a considerable root system in a mineral nutrient solution containing carbohydrate, but that little growth in one to which no nitrate was added. The root would not continue to grow indefinitely under either of these conditions. His conclusion is that the root of a seedling derives some material from the seed other than glucose, the mineral salt, water, oxygen, which are necessary for continued growth and which new roots cannot synthesize in the dark in solution culture from which the materials are supplied.

Turner [1922] suggests that the increase in ratio of top to root, which results from increasing the amount of nitrates in the solution, may be explained on the basis of the increased use of carbohydrates in the top, because the greater nitrogen supply makes for greater growth. This results in decrease in the supply of carbohydrates for the roots, which may bring about an absolute or relative reduction of root growth. This suggestion gives us a clue as to why an application of nitrates at the time of transplanting is not advantageous for then the problem is to have more root growth than top growth.

Reid [1924] substantiates through her work the above results. She found that smaller supplies of carbohydrates were associated with a relatively smaller quantities of roots than shoots. A small supply of nitrogen had a more limiting effect on shoot production than it had on root production. It is the relationship of nitrogen to carbohydrates, not the definite ratio actually, that has an influence on root and top growth. Her work shows that light encourages shoot growth and darkness root growth.

Ellis and Eyster's [1931] work which interests us here is the study of the effect of insulin and glucokinin on maize seedlings of green and non-green type. They found retardation in growth of seedlings grown in distilled water containing per cent of insulin or glucokinin. In the stronger solution, the formation of secondary roots was practically inhibited. In solutions weaker than 0·005 per cent, growth was somewhat increased. This latter concentration of insulin or glucokinin may possibly be exploited for successful corn transplanting, at least on a small scale.

Priestly [1929] did work, which, although on twigs, may suggest another aspect of the use of chemicals in successful transplanting. He found that acids favour the apical organization of the roots, and an alkaline condition, the shoot meristem. Protein leaves the alkaline side rapidly. He found plants in KH_2PO_4, a relatively acid solution, gave buds in three days and roots developed two days later, but when a relatively alkaline solution of K_2HPO_4 was used instead, the roots developed in three days and buds after two weeks. On the basis of these results, he developed a *p*H hypothesis, an understanding and application of which may be greatly exploited for successful transplanting by encouraging root growth.

Some hormones and other growth-promoting substances which can encourage diffusion from one tissue to another of chemical substances which affect permeability, protoplasmic power of synthesis, and cell division, may turn out to be of great help in successful transplanting. Transplantone, a plant hormone, is on the market, a claim for which is made that it reduces wilting and starts growth sooner, without interfering with the proper development and growth of plants. It is being used on trees and shrubs. As to how it would work on vegetables, there is no experimental work to base an opinion upon.

In closing, a little discussion on treatment of plants and cut flowers under water in partial vacuum [Hamner, 1945] may be of great help to understand its significance for successful transplanting. Six inches tall tomato plants under water were subjected to a vacuum of 30 lbs. per square inch for 20 minutes. The coming out of air bubbles from the plant indicated that it is being replaced by water. Plants treated thus were placed at 95° F. and a relative humidity of 20 per cent. The check plants showed wilting after five minutes and after thirty minutes they were badly wilted, while vacuum treated plants showed wilting only after four hours and only half were wilted in seven hours. When these were put into water, most of them recovered, while most of the untreated plants did not recover after they were placed in water.

This vacuum treatment of plants under water is of great significance. Its use on seedlings that are being shipped for long distances especially, would greatly increase their ability to withstand wilting, and so would contribute greatly to the maximum success in their transplanting.

Summary

A successful transplanting is a four-fold problem. First it is a problem of cutting down transpiration below absorption of water by the roots. Second, it is a problem of encouraging prompt regeneration of new root growth. Third, it is a problem of storing water and suitable food material,

both within the plant and around the roots, so that it may not wilt; instead it may initiate new root growth. Fourth, it anticipates a problem of hardening of the plant to enable it to withstand successfully the rigour of the preseason weather. Any method, measure or factor that helps a plant to face these problems successfully, would contribute greatly to successful transplanting.

Hardening makes a plant, not only able to withstand extreme weather conditions, but also cause an accumulation of carbohydrates, which later contributes to prompt initiation of new root growth. The discovery and subsequent use of some carbohydrates, other chemicals with suitable *p*H, and the root-growth-promoting harmones, would undoubtedly be a great contribution to successful transplanting.

The proper use of methylcellulose in field soil or in flat dirt could be a great protection against root drying. It can hold considerable moisture and also would permit least injury to roots at the time when plants are pulled for transplanting. It will also help in reducing the danger from 'damping off', a disease which is very fatal to seedlings.

The knowledge and subsequent use of certain suitable sprays used at the time when plants are pulled for transplanting, could reduce the hazard of wilting. Suitable packages for shipping seedlings, either alone or with the use of a spray, could be used effectively to reduce the danger of root drying and wilting by cutting down the water loss through transpiration. In this respect substances like pliofilm hold great promise.

Partial vacuum treatment of seedlings under water is very effective to enable a plant to delay wilting for several hours. Its use, along with sprays or suitable packages could greatly help the seedling shipping industry. It could also be used locally especially when the wilting danger at transplanting time is great—and this economically too.

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VARIETIES OF LUCERNE (*MEDICAGO SATIVA*) FOR CULTIVATION IN THE PUNJAB

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(With two text-figures)

Lucerne is one of the very important fodder crops of this province; no other perennial fodder crop yields such a high tonnage under irrigation as this crop.

Lucerne is the oldest plant cultivated solely for forage. The expansion in the acreage devoted to this crop has been gradual and has tended to keep pace with the expansion in canal irrigation; but this gradual increase in lucerne cultivation does not mean any lack of appreciation of the high value of the crop, and its importance in the farm economy of the Punjab.

Despite the length of time lucerne has been in cultivation, one is sometimes struck by the paucity of varieties actually being grown today. This fact is, however, no indication that this crop has received little attention as regards the introduction of varieties from other countries with a view to improve the existing situation.

A recently concluded international variety trial, which ran for a period of six years at the Fodder Research Station, Sirsa, and which embraced a comparison of our common varieties with varieties from other provinces in India and abroad, showed fairly conclusively that, over a period of years, varieties from abroad do not compare very favourably with the indigenous varieties. In this trial not only the yielding ability of the variety was made an index of its value, but also such characteristics as longevity of the variety and mortality were kept in view. In addition, it was apparent that the exotic varieties had to contend with the aclimatization factor, whereas varieties, obtained from India, had adapted themselves to local conditions over a long period of years, having been subjected to natural selection. The foreign varieties on the whole showed a marked reduction in yield after a period of a few years mainly through the death of plants.

As a result of these conclusions, it would appear that varieties in cultivation in this country provide good material for cultivation. There is, however, a vast scope for the improvement of present day varieties by means of both breeding and selection work. Although a stage has been set for the improvement of the crop by breeding, several years must necessarily elapse before seed of improved lucerne types can be made available to the growers. Until this work is carried out with success, there is a very limited choice available to the growers; and the results of the experiment, carried out at Fodder Research Station, Sirsa, should be of great interest to the lucerne growers.

Material and methods

Seed was procured both from abroad and from various provinces in India. The varieties from the former source included three from South Africa, viz. African Chinese, African Province, and Hairy Peruvian: one from Tashkent (U. S. S. R) and one from Carters (Great Britain). The varieties from Indian provinces included two from the United Provinces and one from the Central Provinces and one from Poona (Bombay). Some of the characters of these 10 varieties have been given in Table I.

With the limited knowledge of each variety, the grower finds difficulty in the selection of the most suitable, in assessing the benefits he is likely to derive from the cultivation of one or the other variety, and in finding out whether the differences in price of seed are justified. Any short term experiment over a period of two or three years only may be quite misleading, especially in regard to longevity. Taking these points into consideration the results of a varietal trial which was continued for a period of six years should be of interest.

TABLE I

The characters of lucerne varieties

Variety No.	Form of sprouting plant	Height	Tillering	At maturity		Leaf		Flower		Pod		Seed
				Colour of stem	Character of stem	Size	Quality	Colour	Size	Colour	Spirol	
4. Chinese (South African).	Erect	Medium 3·36	Medium 69·2	Green	Thin, filled	Small	Great dark green	Light violet	Big	Smooth brown	2½ screw	Big yellow
6. African Province (South Africa)	Erect	High 3·20	Strong 86·0	With antho-cynine	Thick, more or less filled	Long	Great deep green	Carmine violet	Big	Light smoky	1½ cork screw	Medium yellow
7. Utah (U. S. A.)	Erect	High 3·40	Strong 73·5	With antho-cynine	Thick, filled	Very big	Great green	Carmine violet	Big	Light smoky	2 cork screw	Medium yellow
11. Hairy Peruvian (South Africa)	Erect	High 3·34	Strong 73·6	Green	Thick, filled	Medium	Great green	Light violet	Medium	Smoky	2 cork screw	Medium yellow
14. Poona (Bombay)	Erect	High 3·75	Low 53·4	Light green	Medium, more or less filled	Small	Little	Light violet	Medium	Light brown	½ cork screw	Medium yellow
15. Tashkent 988 (U. S. S. R)	Erect	High 3·36	Medium 79·0	Green	Thin, filled	Medium	Medium	Violet	Medium	Smoky	1½ cork screw	Medium brownish green
U. P. 9	Erect	High 3·2	Strong 57·6	Green	Thick, filled	Big	Great dark green	Light violet	Big	Light smoky	2 cork screw	Yellow
8. (U. P.)	Erect	High 3·10	Strong 98	Green	Thick, filled	Big broad	Great dark green	Carmine violet	Medium	Light smoky	2½ screw	Greenish yellow
21. Neemuch (C.P.)	Erect	High 3·93	Medium 111·1	Green	Thick, more or less filled	Small	Medium deep green	Violet	Big	Brown	2 cork screw	Light brown
23. Carters (London)	Erect	High 3·4	Medium 97	Green	Thick, filled	Big	Great green	Light violet	Medium	Light brown	2½ cork screw	Green brown

The usual method of comparison of yield data from fodder experiments is based strictly on the average yields obtained. While average yields offer the best direct basis of comparison of various plot treatments, they may nevertheless be supplemented with advantage by additional data such as height, tillering capacity, and uniformity of stand. It is possible that the results of the fodder experiments carried out for a period of years may be more interesting when average yields of some of the good varieties are expressed in relation to different environment and seasons as represented by years.

The yield data of the ten lucerne varieties, viz., Nos. 4, 6, 7, 8, 9, 11, 14, 15, 21 and 23 from an experiment conducted at the Fodder Research Station, Sirsa, were available for study. The comparative fodder yield trial was started in 1936-37 and has been carried on up to the end of the year 1942 making the yield data of six year period available.

The test was conducted with these varieties in ten replicated randomized plots, each of which was 1/156th acre in area. The sowing was done by means of a hand drill in rows 1 ft. apart. The germination and stand were very uniform to start with and the crop became ready for first cutting in March 1937, *i.e.* after a period of four months.

Discussion of results

The time and frequency of cutting lucerne are influenced by so many variable factors, such as moisture supply, soil conditions, length of the growing season, intensity and duration of solar radiation, severity of winter seasons, etc., that no cutting schedule could be fixed. The crop was harvested for fodder as soon as the varieties started first flowering. An insect, the leaf hopper (*Empoasca fabae*) had a direct bearing on the time of cutting in the years 1940-41. Leaf hoppers easily cause serious injury, because if the adults lay eggs in the young second growth, severe damage occurs on account of large populations of resulting nymphs. The new crop growth had, therefore, to be cut before it was ready, in order to remove the eggs in the fodder and to reduce infestation of the second growth.

Except the attack of this insect in the years mentioned and the influence of heat combined with humidity during the monsoons, which resulted in numerous casualties in the stand of the crop, no other factor was observed to have caused any retardation in growth. The yields of green fodder obtained during the course of the experiment show clearly how each variety responded to these conditions. The average yields of green fodder obtained from each variety in the six years were analysed according to Fisher's method of analysis of variance, and are given in Table II.

Table II

The yields of green fodder and cuttings of the ten lucerne varieties during the period 1937-42 at the Fodder Research Station, Sirsa

Yield per acre in maunds.

Year	No. of cuttings taken during the year	4	6	7	8	9	11	14	15	21	23	Significance		Remarks
												1 per cent	5 per cent	
1937	6	204	304	331	499	445	232	433	402	328	281	..	6·6	
1938	10	585	757	753	1108	1053	304	113	1006	869	445	9·67	7·03	
1939	8	782	1021	908	1135	1140	421	59	1180	1013	560	13·45	9·98	
1940	11	690	916	893	1040	1119	363	19	1091	870	491	14·16	10·73	
1941	11	530	720	768	889	913	261	8	807	725	473	33·75	25·46	
1942	9	270	423	496	627	656	111	2	589	473	138	30·4	23·1	
Average yield per acre		521	692	707	883	888	282	107	861	713	398			

The yield per acre of green fodder obtained during the year 1942, together with the average yield produced over the whole period of six years of the experiment from 10 varieties, is given in Table III.

TABLE III

Yield of green fodder per acre in maunds

Variety	Average of 6 years 1937-42	1941-42
4	521	270
6	692	423
7	706	496
8	883	627
9	888	656
11	282	111
14	107	22
15	861	589
21	713	473
23	398	138

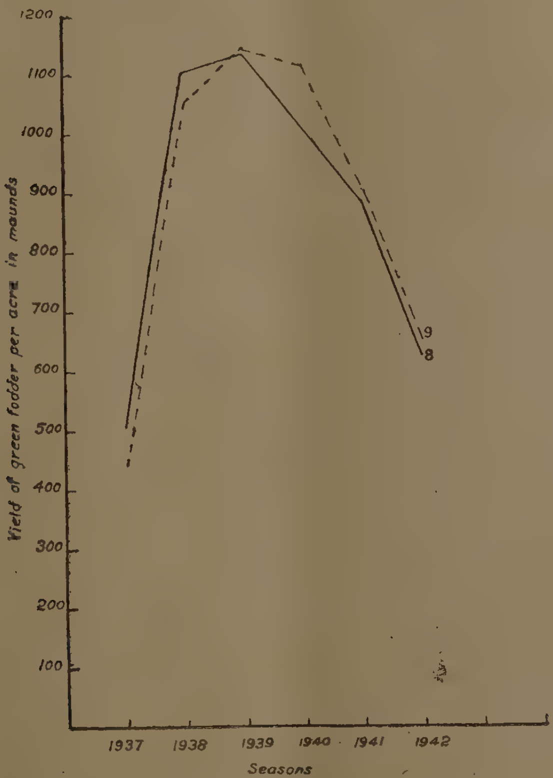

Fig. 1. Average yields of lucerne Nos. 8 and 9 from year to year

Average yields per acre of all the varieties tried and those recommended for cultivation in the Punjab, viz. 8 and 9 are further presented graphically, showing the relative yields from year to year (Fig. 1).

It will be noticed that even after six years the yields remain high in the case of Nos. 8 and 9 and to some extent in Nos. 7 and 15, while that have fallen considerably in all the others. These results support the statement that exotic varieties from abroad, viz. Nos. 4, 6, 11 and 23 do not maintain their yields over a long period of years like the more commonly grown country varieties.

Nos. 8 and 9 showed definite superiority in respect of yield and, in addition, maintained their lead throughout the experiment; No. 15 stood third in total yield and out yielded all varieties in the experiment in 1939. The differences between the total yields of Nos. 8 and 9 were almost negligible as is seen in Fig. 2.

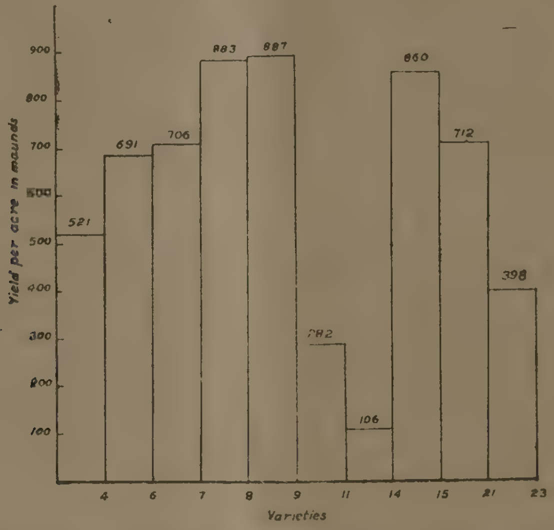

FIG. 2. Average yield of green fodder of 10 lucerne varieties over a period of six years.

These results have been further corroborated by the results of other experiments with some of these varieties at other departmental stations. Table IV gives the yield of green fodder per acre at Montgomery, Hansi and Gurdaspur Agricultural Stations.

TABLE IV

The yield of green fodder per acre in maunds

Year	Station	Local	Varieties					Significance	
			6	8	9	15	21	1 per cent	5 per cent
1939-40	Montgomery	207	345	375	368	342	339	18·02	13·37
1940-41	Montgomery	425	672	762	692	690	677	18·69	13·86
1941-42	Montgomery	501	715	795	686	743	689	18·44	13·69
1940-41	Hansi	..	..	186	195	157	..	..	..
1941-42	Hansi	..	..	496	518	445	..	..	..
1941-42	Gurdaspur	..	..	394	343				

From an examination of Table II it will also be observed that during the first year Nos. 8, 9, 14 and 15 yielded more than 400 maunds of green fodder per acre, and only small differences were discerned among them: but in the second year of their growth, No. 14 was the poorest yielder. There was, however, insignificant difference among the other three varieties which yielded more than 1,000 maunds in ten cuttings. These three varieties Nos. 8, 9 and 15 maintained their superiority over

others throughout the remaining period of the experiment. But in the sixth year, Nos. 8 and 9 gave comparatively higher yields than No. 15.

Nos. 8 and 9 yielded, on the average of six years 882 and 887 maunds of green fodder per acre respectively. In the sixth year, however, they gave an outturn of 627 and 656 maunds per acre respectively which is higher than all others.

Apart from the yielding abilities of the different varieties, longevity of a variety is a very desirable character and may be influenced by soil conditions, fertility and available moisture, hoeing, and weeding of the crop. However, varieties growing under equal conditions do manifest considerable variation in vigour and ability to last, and this can be seen in Table V which gives the number of total plants of each variety in the year 1940 after a period of four years.

TABLE V

The number of total plants in each variety in the experiment after a period of four years

Variety	No. of total plants in 10 repeats
4	1621
6	1884
7	1998
8	1993
9	3268
11	546
14	26
15	2241
21	1862
23	395

The amount of space covered by each variety during the fourth year as shown by the number of plants varied to a very great extent. Although the amount of ground covered by Nos. 8, 9 and 15 also show great variation, it is the highest in case of No. 9 while low in the case of Nos. 8 and 15. From the figures presented above, it would appear that No. 9 after 6 years had a much better stand of plants than Nos. 8 and 15; No. 8 with a comparatively lower number maintained its yielding ability due to vigorous growth and bigger stools. Other varieties have not only shown poor ability to survive, but in addition there has been marked encroachment by weeds. No. 14, which yielded about equal to these superior varieties in the first year, gave the poorest yields later on, because of the largest number of post germination resulting in plant casualties. These varieties, i.e. Nos. 8, 9 and 15 reached a stage in the sixth year at which it was considered uneconomical to retain them any further.

It has already been mentioned that none of the varieties, viz. 8, 9 and 15 can be identified from their vegetative characters when grown side by side. However, differences in vigour of their growth were notable.

No. 9 is erect and vigorously growing, tillers profusely, with numerous branches. Its leaves are medium sized and dark green in colour, flowers light violet, mature pod light smoky and of medium size with plump kidney shaped seeds light yellow in colour. No. 8 is also an erect and a vigorously growing variety. It tillers profusely and each tiller has several branches. Leaves are broad and dark green in colour, flowers violet, mature pods light smoky and of medium sized with plump, kidney shaped seeds yellowish in colour.

Both have given exceedingly good account of themselves and have been placed on the list of approved seeds of the Agricultural Department, Punjab.

SUMMARY

Until such time as improved strains of lucerne are put on the market, the varieties Nos. 8 and 9 are superior to others under irrigation, and have been recommended for cultivation.

These varieties not only gave high yield of green fodder from the very start, but maintained their high yielding ability for a large number of years.

The high yields are due mostly to their uniformly good stand throughout the period of six years. No. 9 covered the maximum amount of space but No. 8 compensated for it by quick growth and high tillering ability.

In addition to the high fodder yield, ability to survive over a number of years is an important factor determining the selection of a variety. No. 9 was superior to all others in this respect as it had the least number of pest germination resulting in plant casualties, Nos. 8 and 9 both have, therefore, been recommended for cultivation in the Punjab.

A PRELIMINARY NOTE ON THE ESSENTIAL OIL BEARING PLANTS GROWING IN KASHMIR, II

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(Received for publication on 6 November 1946)

In a previous paper [Chopra *et al* 1946] we gave the results of investigations carried out in the Drug Research Laboratory in connexion with the essential oil bearing plants growing in Kashmir. In some the yield of the essential oil was too small for commercial exploitation while in others it was promising. This latter group has been taken up for detailed investigations and the results of these studies will be communicated in due course.

Since then a number of other plants with reputed aromatic properties have been collected in course of our botanical excursions in different parts of Kashmir. The results of preliminary investigations on these plants are reported in this paper.

The plants mentioned below have been studied :—

Acorus calamus. (*Sweet flag ; Vern. Bach, Vai*).

This plant is a semi-acquatic perennial herb with an indefinitely branched rhizomes. It is originally a native of Europe and North America but has been cultivated in India in damp marshy places at altitudes of 3,000 to 6,000 ft. above the sea level. In Kashmir it grows on the borders of lakes and marshy areas. The rhizomes are used in the indigenous medicine as emetic, nauseant, antisposmodic and carminative ; they are also used in the treatment of asthma, diarrhœa and dysentery [Chopra, 1933]. In foreign countries the normal oil of sweet flag is used as a perfuming material and also as an ingredient in imparting flavour to gin and some types of beers.

The fresh and unpeeled rhizomes of the plant were steam-distilled and an oil with a brownish yellow colour and agreeable odour was obtained. The properties of this oil were studied and compared with the foreign oil [Glidemiester and Hoffmann, 1922] as given below :—

——	Local oil	Indian oil	Foreign oil
Yield of the oil from unpeeled rhizomes	3·1 per cent	1·5 to 3·5 per cent	1·5 to 3·5 per cent
Specific gravity	1·08 at 15°C.	1·069 at 15°C.	0·959 to 0·97 at 15°C.
Refractive index	1·5475 at 20°C.	....	1·5028 to 1·5078 at 20°C.

Cinnamomum tamala (*Vern. Tejpat, Dalchini*)

Official cinnamon oil is obtained from the bark of *Cinnamomum zeylanicum*, a tree which is indigenous to Ceylon. This oil is carminative and has antiseptic properties and is used in medicine.

Cinnamomum tamala grows wild in the Rajouri and Kathua forests of Jammu province in Kashmir State. The bark possesses a cinnamom-like odour and the leaves are used locally in place of

cinnamon bark. In order to determine if this species of cinnamomum can be exploited for the production of cinnamom oil, both the dry leaves and bark were steam-distilled and a light brown oil was obtained. The properties of this oil were studied and compared with the oil obtained by Schimmel and Co. from the East Indies [Gildemiester and Hoffmann, 1922] as given below :—

——	Local oil	Foreign oil
Yield of the oil from dry bark	0·05 per cent	....
Yield of the oil from dry leaves	1·2 per cent	....
Specific gravity	1·023 at 15°C.	1·0257 at 15° C.
Refractive index	1·5775 at 20°C.	1·52596 at 20°C.

Hyssopus officinalis (*Vern. Zufah-yabis*)

Hyssop oil is mainly distilled from *Hyssopus officinalis* which is indigenous to countries bordering on the Mediterranean sea and also in Central Asia. The plant grows in Baluchistan and in the Himalayas at altitudes ranging from 8,000 to 11,000 ft. It is not indigenous to Kashmir Valley but has been successfully cultivated in the Forest nursery at Baramulla.

The leaves of the plant are used in the indigenous medicine as a stimulant, stomachic, expectorant, diaphoretic and as an emmenagogue [Chopra, 1933]. Hyssop oil is also much esteemed for flavouring purposes and is said to be an ingredient of some of the French liquors [Parry, 1925].

Both the fresh and dry herb procured from the forest nursery were steam distilled and a brownish yellow oil with aromatic odour was obtained. For comparison the properties of the local oil and that of the foreign oil [Gildemiester and Hoffmann, 1922] are given below :

——	Local oil	Foreign oil
Yield of the oil from fresh herb	0·36 per cent	0·07 to 0·29 per cent.
Yield of the oil from dry herb	0·7 per cent	0·3 to 0·9 per cent.
Specific gravity	0·9375 at 15°C.	0·927 to 0·945 at 15°C.
Refractive index	1·4778 at 20°C.	1·473 to 1·486 at 20°C.

It appears from the data given above that the yield of the oil from the herb and the physica constants of the oil compare favourably with those of the foreign oil. The plant has acclimatized well for artificial cultivation in Kashmir Valley and can be commercially and economically exploited.

Angelica glauca (*Vern. Chora*)

This plant grows in abundance in moist places at altitudes of 7,000 to 9,000 ft. and is very common in Kisehnaganga Valley. Locally the root is much used by the inhabitants as a spice ; it is also used in the indigenous medicine in the treatment of dysentery, constipation and as stimulant and cordial tonic. In the foreign countries the Angelica oil obtained from *Archangelica officinalis* is used in perfumery and in flavoring of liquors.

The dry roots of the plant were steam-distilled and a brown yellow oil with the following properties was obtained. The constant of the foreign oil [Gildemiester and Hoffmann, 1922] are also given below for comparison.

——	Local oil	Foreign oil
Yield of the oil	13 per cent.	0·35 to 1 per cent.
Specific gravity	1·0275 at 15°C.	0·859 to 0·918 at 15°C.
Refractive index	1·529 at 20°C.	1·477 to 1·488 at 20°C.

Salvia species

Sage oil which is largely used in foreign countries is obtained from *Salvia officinalis* which is indigenous to the Mediterranean area and is also cultivated in many countries with temperate climate as an ornamental plant and also for its medicinal properties. The oil is largely distilled in Dalmitia and its yield ranges from 1·3 to 2·5 per cent [Parry, 1925].

A number of species of *Salvia* grow wild in the hills bordering on the valley of Kashmir. These are reputed both for their medicinal and aromatic properties. The species which commonly occur here are: *Salvia moorcraftiana* (Vern. *Kalijarri*), *S. glutinosa*, *S. dumitorum*, *S. hians*, *S. latana*, etc. In order to see if these species can be suitably exploited for the production of Sage oil of commerce the first named four species were collected from the Sindh division in Kashmir. The dry leaves and flowering tops were steam-distilled and the following yields of the oils were obtained :

1. *Salvia moorcraftiana*	0·25 per cent
2. *S. glutinosa*	0·32 per cent
3. *S. dumetorum*	0·34 per cent
4. *S. hians*	0·24 per cent

The percentage yield of the oils of these species is so low that no economic exploitation of these can be undertaken. It is, however, possible that the yield of the essential oil may increase on cultivation on suitable soil. This will be tried. The other species are under investigation and their results will be communicated in due course.

Elsholtzia species. Many species of *Elsholtzia* are found growing wild in valley of Kashmir but only two species for the present have been studied for their essential oil contents. These are *E. cristata* and *E. densa*.

Elsholtzia cristata. This plant was used in the indigenous medicine as an antipyretic and diuretic but this has now been given up. It grows wild in Kashmir Valley on the banks of streams. The dry herb was steam distilled and a yellow oil, turning brown on standing, was obtained. The properties of the local oil were studied and compared with the foreign oil [Gildemiester and Hoffmann, 1922] are given below :

——	Local oil	Foreign oil
Yield of the oil	0·93 per cent	2·00 per cent
Specific gravity	1·023 at 15°C.	0·970 at 15°C.
Refractive index	1·529 at 20°C.	—

Elsholtzia densa (*Vern. Poodina*). This is an annual herb found commonly in Sindh division of Kashmir Valley. The whole dried herb was steam distilled and a brownish coloured oil with the following properties was obtained :

Yield of the oil	0·98 per cent
Specific gravity	0·9697 at 15°C.
Refractive index	1·4675 at 20°C.

Heracleum Vcachemiricum

This plant is commonly found wild in the mountain regions in Kashmir especially in the Gurez Valley up to an altitude of 11,000 ft. The fruits and leaves of this plant have aromatic properties.

The dry fruits collected in the month of September were steam distilled and a brownish oil with the following characteristics was obtained :

Yield of the oil	0·8 per cent
Specific gravity	1·0304 at 15°C.
Refractive index	1·504 at 20° C.

Artemisia species

Many species of *Artemisia* are found growing wild in Kashmir Valley and some of them are economically exploited here, e.g. *Artemisia brevifolia*, for the production of santonine. *Artemisia absinthium* which yields the wormwood oil also grows abundantly in Kashmir.

With a view to study the essential oil contents of these species the following plants were collected.

1. *Artemisia dracunculus*
2. *A. laciniata*
3. *A. amygdaliana*
4. *A. grata*
5. *A. parviflora*

Artemisia dracunculus yields the estrangon oil of commerce which is largely used in conserves and in the preparation of aromatic vinegar. The flowering shoots of the above plant were steam distilled and a brown oil was obtained. The yield and other properties were determined and compared with the foreign oil [Gildemiester and Hoffmann, 1922].

——	Local oil	Foreign oil
Yield of the oil	0·7 per cent	0·25 to 0·8 per cent
Specific gravity	0·9492 at 15°C.	0·900 to 0·945 at 15°C.
Refractive index	1·5235 at 20°C.	1·502 to 1·514 at 20°C.

The other four species yielded on steam distillation only traces of essential oil; therefore, their other properties could not be studied.

Macrotomia benthami. (*Vern. Gaozaban*)

The plant grows wild at altitudes of 10,000 ft. and is largely met with in Gurez and Chota Deosai in Kashmir Valley.

Water, *sharbet* and jam prepared from the flowering shoots is extensively used by *hakims* in deseases of tongue and throat and in the treatment of fevers [Kaul, 1928].

The whole of the dry plant was steam distilled but essential oil could only be extracted in traces.

Rhus succeedana (*Vern. Arkhar*)

This plant commonly grows in the forests of Kashmir and is reputed for its aromatic properties. Both dry fruits and leaves were steam distilled but only traces of the oil were obtained.

Vitex negundo (*Vern. Nergundhi*) *and Lantana camara* (*Vern. Vhaneri*)

These are both extensively used in the indigenous medicine and are reputed for their aromatic properties. On steam distilling the dry flowering shoots of these plants, very little of the essential oil was obtained. The results of detailed studies on these plants will be communicated in due course.

ACKNOWLEDGEMENTS

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A NEW METHOD FOR THE DETERMINATION OF THE AVERAGE DIAMETER OF TEXTILE FIBRES, FILAMENTS, FINE WIRES, ETC.

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(With three text-figures)

The fineness of the cotton fibre which is determined by the diameter of the original cell is a very important criterion of the spinning quality of a sample of cotton, especially in the long staple cottons. The method of studying this character is generally the microscopical method which is not only strenuous but time-absorbing and for this reason the fibre diameter is not generally studied. The object of the present investigation is to develop a method by means of which the average diameter of a large number of fibres could be determined accurately and quickly. The method developed is applicable not only for cotton fibres but also for other fibres hairs, fine wires, etc.

Theory

The theoretical basis of the present investigation is as follows. A beam of light of uniform intensity passing through an accurately made slit falls on a photoelectric cell and the photoelectric current (I_1) produced is measured. If it is assumed that the current is proportional to the area of illumination, then

$$I_1 = k.\, wl \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where k is a constant and w and l are the width and length of the slit respectively. Next a parallelised tuft of opaque fibres, filaments, etc., with as little overlapping as possible, is interposed in the path of the beam perpendicular to the length of the slit. The area of illumination is now reduced by an amount equal to $n\, w\, d$, where n is the number and d is the average diameter of the material under study. If the intensity of illumination remains the same as before the current, I_2, is given by

$$I_2 = k\,(wl - n\, w\, d) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

From (1) and (2) it follows that

$$d = \frac{l}{n} \cdot \frac{I_1 - I_2}{I_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The terms on the right hand side of (3) are all known excepting n, which can be counted either with the naked eye or with the help of a low-power microscope and from the knowledge of this d can be calculated.

The two assumptions necessary to satisfy this equation are (1) that the fibres, filaments, etc. are opaque to the light and (2) that there is not any appreciable overlapping. If the fibres are not originally opaque it may be possible to render them opaque by dyeing. The condition for avoiding the overlapping may be satisfied either by mounting the fibres, filaments, etc., individually or by taking sufficient care in the process of parallelisation to ensure that there is not appreciable overlapping. In actual practice it is possible to satisfy both these conditions in most cases.

Experimental

(*a*) *Apparatus*. The apparatus shown schematically in Fig. 1 essentially consists of a hollow cylinder supported on two uprights. An electric lamp placed at one end of the cylinder is fed with a constant current of 1·8 or 1·9 amperes from an 18 volt storage battery. A fine variable resistance and a sensitive ammeter are used in the circuit to maintain the current constant, which is essential for the accuracy of the final result. A condenser and suitable diaphragms are provided to obtain a beam of light of uniform intensity which is made to pass through a water-cell for absorbing the heat rays. The light emerging from the water-cell passes through an accurately made slit, 30 mm.

long and 5 mm. wide. The plate of this slit is provided with a suitable stand for holding the slide on which the fibres, filaments, etc. may be mounted. These slides can be interchanged rapidly to enable a fairly large number of readings to be taken on the same or different materials. The light emerging through the slit falls on the photoelectric cell, placed at the other end of the cylinder as near the slit as possible. The cell is of the Weston 'Photronic' type and is connected in series with a resistance of about 500 ohms to a Cambridge and Paul ballistic galvanometer, with a shunt of 100 or 150 ohms.

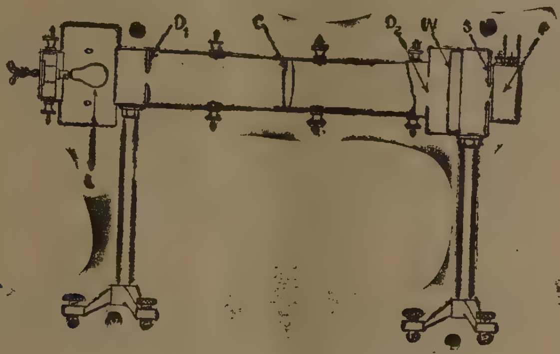

FIG. 1. The apparatus shown schematically

(*b*) *The slide and its use.* The slide mentioned above is an important feature of the apparatus as it helps the preparation, within a few minutes, of a parallel tuft of cotton fibres with very little overlapping, which is a serious source of error in this work. It is a modification of the Ahmad and Gulati [1936] slide, with velveteen pads in place of the fibre pads. As shown in Fig. 2 it consists of two pairs of pads A and B. At the commencement the upper pads of A and B are removed and the lower pads are kept flush to each other. A thin tuft of about 150 fibres, one layer thick, is extracted from a prepared sliver by means of a tweezer and is placed carefully on the slide such that the aligned end caught by the tweezer lies on the fixed pad A, near its edge and that the fibres lie without overlapping on the movable pad B, perpendicular to the edge. Now the upper pad of A is inserted and screwed on to hold one end of the fibres tightly. Next the upper pad of B is also inserted and pressing it gently B is pulled apart from A slowly until the required length of the fibres is exposed, when the upper pad of B is screwed tightly. Now holding A and B apart such that a small tension is exerted on the fibres, B is fixed in this position. The combing action on the fibres when pulled through the velveteen pads effects good separation and parallelisation and the whole process gives a tuft of parallel stretched fibres with little overlapping.

In the later work the overlapping was further reduced by using the following technique. The fibres mounted in the slide as stated above were viewed with a pair of binocular magnifying glasses and the fibres found overlapping were separated out with a needle. A few fibres that continued to overlap and a few short fibres that did not occupy the whole region between the pads were pulled out with a pair of fine forceps. By this procedure the overlapping was made very small.

It should be stated, however, that the overlapping cannot be reduced beyond a certain minimum. It is, therefore, necessary to determine the average number of fibres that lie across a certain section of the slide. For this purpose the number of fibres was counted by moving the slide under the microscope perpendicular to the length of the fibres, very low magnification being used so as to bring the fibres in the different planes within the focus. While counting, the fibres crossing the pointer end of the pointer eye-piece were examined carefully. If two fibres overlapped completely at this point they were counted as one. If, however, the overlapping was partial discretion was used to allot the number but this certainly is a source of error. It will be found later that though this error was perceptible with the first method of mounting, it almost completely disappeared with

the improved technique. The counts were made at three sections along the length of the fibre and the mean of the three was finally taken as the average number.

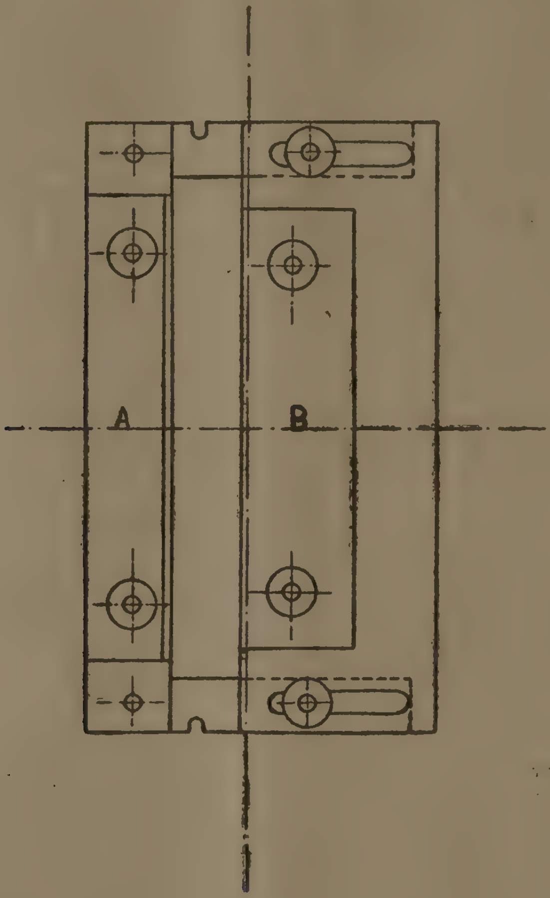

FIG. 2. The diagram of the slide

(*c*) *Mercerising and dyeing.* The cotton samples were first mercerised with 18 per cent caustic soda solution in order to make the cross-section of the fibres nearly circular. After washing, scouring and washing again the fibres were made opaque by dyeing in a boiling solution of chlorozol black for about 15 minutes. Material other than cotton which was not opaque was also dyed similarly. The dye solution contained by weight 1 per cent chlorozol black dye, 10 per cent glauber salt crystals and 89 per cent distilled water. About 10 c.c. of the solution were used for about 100 mg. of the cotton sample. After dyeing the cotton was washed in running water until the water was free from colour. The cotton was then squeezed out by hand and dried in an oven at a temperature of about 105°C.

Whether the dyeing process modified the fibre diameter to any appreciable extent was the next point to be ascertained. This was done by finding the diameter of several samples of cotton microscopically both before and after the dyeing but the values obtained showed no significant variation.

(*d*) *Photoelectric current or voltage.* Before taking up the actual work one point had to be decided, namely, whether to use the current or the voltage characteristic in the present study. A preliminary enquiry was, therefore, made and the diameter was calculated using both the properties.

When these values were compared with the values of the diameter as determined microscopically, it was found that the diameter calculated from the current agreed more closely. Besides the variability between the individual readings was found to be less in the case of the current values. Moreover the values of the diameter obtained from the voltage data were, in all cases, less than those from the current data, which divergence is found to have a theoretical basis as shown in the Appendix. Furthermore the makers of the 'Photronic' cell also advocate the current characteristic as it is less influenced by temperature changes. In addition to these, the experimental arrangement for the determination of the voltage is much more cumbersome than that for the current, which, within the limits of the present study, was found to be proportional to the galvanometer deflection. Hence both from the practical and from the theoretical points of view, the current characteristic is to be considered the more reliable criterion and, therefore, that has been used in the present investigation.

(*e*) *Proportionality of the photoelectric current and the area of illumination.* The next point to be decided was whether the photoelectric current produced was proportional to the area of illumination when the intensity of the source of light was kept constant. This was done in two ways, firstly by reducing the length of the slit by pasting strips of black paper at the two ends and secondly by interposing across the slit varying numbers of brass rods of average diameter 0·089 cm. In the former case the slit remains a continuous one while in the latter it becomes discontinuous. The results obtained are graphically represented in Fig. 3. The 45° line denotes absolute proportionality and it will be noticed that in the case of the continuous slit the curve departs very little from this line except when the area of the slit is as small as about 50 per cent of the whole slit. In the case of the discontinuous slit also the departure from proportionality is small when the decrease in the area is small but it becomes pronounced when the decrease in area is large. The theoretical basis for this departure with reduced illumination in both cases is probably due to the corresponding increase of photo-cell resistance. Whether the greater divergence observed in the case of the discontinuous slit is real or is due to experimental errors requires to be determined. If it is real, whether it is due to diffraction causes is considered in the next section. But this point is not material for our present purpose for within the limits of the present studies, namely, up to about 80 per cent of the area of the full slit, the photoelectric current is, for all practical purposes, proportional to the area of illumination.

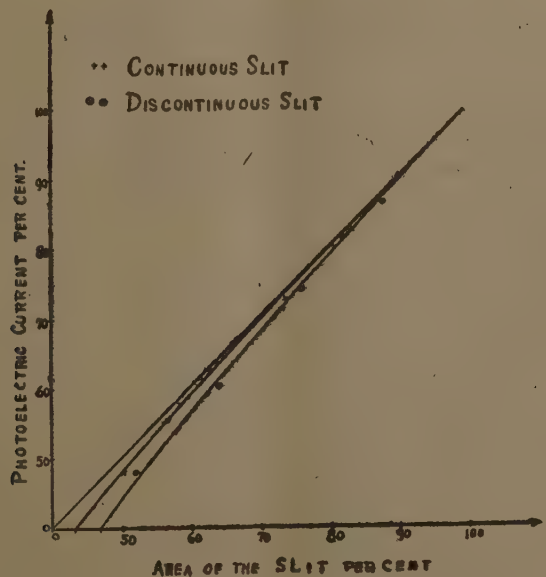

Fig. 3. The relation between photoelectric current and slit area

(*f*) *Effect of diffraction.* The greater divergence from the proportionality of the current and the area of illumination observed above in the case of the slit superposed with a few rods leads one to suspect that the departure may be due to diffraction causes. If the diffraction caused by the few rods produced such an amount of variation, then the large number of fibres should really produce considerably greater variation. But when the values of the diameter obtained by the photoelectric method were compared with those obtained microscopically it was found that, in all cases, the difference was small and within experimental errors. This means that the effect of diffraction is not as large as expected. It should be so from *a priori* considerations also, for what the diffraction does is not to destroy any energy but simply to shift the point of incidence. Moreover in the apparatus the diffraction effect has been made as small as possible by placing the photoelectric cell very near the slit, the distance between the latter and the active surface of the cell being hardly 5 mm.

(*g*) *Method of procedure.* In the preliminary studies for the accurate determination of the diameter, single filaments, fibres and wires were mounted individually using a heated mixture of sealing wax and paraffin wax. In the work on cotton fibres the slide mentioned above was used. Generally five determinations of I_1 and I_2 were made alternately for each test. In the case when individual filaments and wires, etc., were mounted four such tests were made on each slide. On the other hand, for the cotton samples four separate slides were tested for each sample. In each case the diameter of the material was also determined by means of the microscope for purposes of comparison.

(*h*) *Material.* The materials studied covered a wide range from the point of both substance and diameter. They were copper wire, silver wire, human hair, wool fibres, natural and artificial silk filaments and several samples of cotton fibres. The diameter ranged from 12μ to 117μ. In the case of the cotton samples, the standard Indian cottons ranging from the coarsest to the finest were examined in two sets. While for the second set of ten samples the improved technique of mounting was employed it was not used for the first set of 15 samples.

About 100 mg. of the cotton sample was found sufficient for the test. Cleaning and separation of the fibres before mercerising and dyeing considerably aided the preparation of the sliver afterwards. The front delivery roller (No. 33) of the draw box of the Balls sorter was made of half its usual diameter to facilitate the preparation of the small sliver.

Results

(*a*) *Fibres, filaments, etc.* The mean values of the diameter along with the standard errors for the fibres, filaments, etc., are given in Table I.

Table I

Diameter (in μ) of fibres, filaments, wires, etc.

No.	Substance	Photoelectric * P	Microscopical ** M	Difference $P-M$
1	Natural silk	12·4±0·13	12·2±0·24	+0·2±0·27
2	Wool fibre	24·0±0·56	23·3±0·36	+0·7±0·67
3	Art silk	24·4±0·69	24·3±0·96	+0·1±1·22
4	Ditto	26·4±0·11	26·4±0·47	0·0±0·48
5	Silver wire	47·2±0·53	47·3±0·21	—0·1±0·57
6	Human hair	74·3±0·87	75·7±0·63	—1·4±1·07
7	Copper wire	124·6±1·35	116·7±0·73	+7·9±1·53

* Mean of four tests on one slide

** Mean of all the material mounted on the slide

It will be noticed that the diameter of the materials ranges from 12μ to 117μ and in all cases except for the copper wire the difference between the value obtained by the photoelectric method and the microscopical method is non-significant indicating a close agreement between the two sets of values. The significantly higher value obtained by the photoelectric method for the copper wire is probably due to the fact that the wires were not perfectly straight. The slight bend would increase the length of the wire by a small amount but for purposes of calculation the length is taken as 5 mm. only. The consequent error is reflected in the higher value of the diameter obtained.

(*b*) *Cotton samples.* The values of the fibre diameter obtained for the first 15 cottons are recorded in Table II and the analysis of variance of the data is given in Table III.

TABLE II

Diameter (in μ) of cotton fibres by the photoelectric and microscopical methods : Fifteen Standard Indian Cottons of 1935-36 and 1936-37 seasons

No.	Cotton	Photoelectric * P	Microscopical ** M	Difference P—M
1	*Verum 262, Nagpur (1935-36)*	15·5±0·44	15·3±0·22	+0·2±0·49
2	*Mollisoni*	18·5±0·57	18·8±0·31	—0·3±0·65
3	*Umri Bani*	15·1±0·34	15·6±0·27	—0·5±0·43
4	*Co. 2 (1936-37)*	15·8±0·49	15·5±0·26	+0·3±0·55
5	*Sind N. R.*	17·9±0·19	18·6±0·27	—0·7±0·33
6	*Surat 1027 A.L.F.*	17·1±0·17	17·1±0·28	0·0±0·33
7	*Hagari 1*	15·7±0·91	15·6±0·30	+0·1±0·96
8	*Karunganni C.7*	15·6±0·85	15·7±0·24	—0·1±0·88
9	*Nandyal 14*	14·4±0·41	14·1±0·21	+0·3±0·46
10	*C.402*	15·5±0·51	15·6±0·25	—0·1±0·57
11	*Verum 434 (Akola)*	15·8±0·80	15·8±0·22	0·0±0·83
12	*P.A. 289F*	13·9±0·48	13·4±0·19	+0·5±0·52
13	*Co. 2 (1935-36)*	15·3±0·53	14·4±0·24	+0·9±0·58
14	*Wagad 8*	18·8±0·28	18·3±0·42	+0·5±0·50
15	*Verum 262, Nagpur (1936-37)*	15·4±0·38	15·3±0·22	+0·1±0·44
	Mean	16·01	15·93	+0·08±0·41

* Mean of four slides ** Mean of about 150 fibres

TABLE III

Analysis of variance of the photoelectric values for the 15 cottons

Variance due to	Degrees of freedom	Sum of squares	Mean square	S. D.
Cottons	14	561·6049	40·1146	..
Between slides	45	51·4115	1·1425	1·069 (6·7 per cent)
Within slides	240	64·7720	0·2699	0·5195 (3·2 per cent)
Total	299	677·7884	..	..

It will be noticed (Table II) that the fibre diameter varies from 14·4μ to 18·8μ among the 15 cottons. In all cases the difference between the photoelectric value and the microscopical value is not significant. The mean difference for all the 15 cottons taken together is ±0·08, ±0·41 which is also non-significant. This means that, as with filaments and wires, in the case of the cotton fibres also the value of the diameter obtained by the photoelectric method agrees closely with that obtained microscopically.

Next if the analysis of variance is considered it will be seen (Table III) that the variance between cottons is significant and also large, as is to be expected with the wide range of cottons studied. The variance between slides is also significant showing that the difference between slide and slide is definitely more than the error of the experiment with one slide. The former is made up of three factors, (1) the photoelectric error of the determination, (2) the error due to the variation of the fibre diameter within a sample of cotton and (3) the error caused by the overlapping of the fibres. Of the three, the second is incident in the sample and cannot, therefore, be overcome. The first one is due to the method of measurement employed. In the present work this error is 3·2 per cent for a single set of observations or 1·43 per cent for the mean of five such observations. It may possibly be reduced further by using more precise arrangement for maintaining constant current in the lamp. Even as it is, it is of the same order as that obtained by the microscopical method when about 150 fibres are examined. Therefore, this factor too cannot be considered large. Coming to the third factor it should be pointed out that in the present 15 samples of cotton, the fibres were separated and parallelised by merely pulling them through the moving pair of pads of the slide. The improved technique of mounting by means of which the overlapping and short fibres were eliminated was not used in this case. It was used for another set of ten cottons, the results for which are given in Table IV, the analysis of variance being shown in Table V.

TABLE IV

Diameter (in μ) of cotton fibres by the photoelectric and microscopical methods : Ten standard Indian cottons of the 1943-44 season

No.	Cotton	Photoelectrical * P.	Microscopical ** M	Difference P—M
1	*Jayawant*	15·2±0·30	15·4±0·25	—0·25±0·39
2	*Surat 1027 A.L.F.*	17·3±0·36	16·9±0·31	+0·4±0·48
3	*Nandyal 14*	14·1±0·22	14·4±0·31	—0·3±0·38
4	*Wagad 8*	17·8±0·30	18·1±0·32	—0·3±0·44
5	*Jarilla*	15·2±0·35	15·0±0·28	+0·2±0·45
6	*Gadag 1*	14·4±0·32	13·7±0·20	+0·7±0·38
7	*Co.2*	14·8±0·36	14·0±0·29	+0·8±0·46
8	*Sind Sudhar*	13·1±0·36	13·0±0·20	+0·1±0·41
9	*P. A. 298F/K.25*	14·4±0·31	13·8±0·23	+0·6±0·39
10	*Mollisoni*	17·6±0·27	17·3±0·28	+0·3±0·39
	Mean	15·39	15·16	+0·23±0·41

* Mean of four slides ** Mean of about 150 fibres

TABLE V

Analysis of variance of the photoelectric values for the ten cottons

Variance due to	Degrees of freedom	Sum of squares	Mean square	S. D.
Cottons	9	476·3364	52·9263	
Between slides	30	12·1780	0·4059	0·637 (4·1 per cent)
Within slides	160	57·6280	0·3602	0·600 (3·9 per cent)
Total	199	546·1424		

It will be noticed (Table IV) that in the case of these ten samples of cotton also the difference between the values of the diameter obtained by the photoelectric and microscopical methods is not significant. The mean difference for the ten cottons taken together is $+0{\cdot}23 \pm 0{\cdot}41\mu$, this is also non-significant as was found previously (Table III). On the other hand, the variance between slides is not significant unlike what was found before, which means that the improved method of mounting by eliminating the overlapping or by reducing it to a minimum has considerably lessened this error. The standard deviation between slides is 4·1 per cent which gives a critical difference ($P \pm 0{\cdot}05$) of about 1·8, 1·2, 1·0, 0·9 and 0·8 for the mean of 1, 2, 3, 4 and 5 slides respectively. Hence if two slides are tested for one sample of cotton a critical difference of $1{\cdot}2\mu$ is to be expected which amount of accuracy is sufficient for practical purposes. If, however, greater accuracy is needed more slides have to be tested.

It will be observed that the photoelectric error in the case of these ten cottons is 3·9 per cent which is of the same order as was found in the previous case for the 15 cottons.

Discussion

From the foregoing it is clear that the method of finding the diameter described above gives accurate results, the values obtained agreeing closely with those got by the microscopical method. Besides the errors involved are also small enough for practical purposes. Furthermore this method has additional advantages over the microscopical method, namely, that considerably greater number of fibres are examined and that the average diameter over a long region of the fibres is obtained by this method. The time factor, however, has not been considered so far and it may be done now. The time taken for the photoelectric readings is hardly ten minutes for one slide. If the 'photronic' cell is good, the current for repeated exposures remains absolutely constant. In such a case it is not necessary to insert the slide containing the fibres and remove it alternately to get the readings of I_1 and I_2. The five readings of I_2 can be taken one after the other and half the readings of I_1 can be taken before and the other half after taking the I_2 readings. This will reduce the time still further. The time for mounting the fibres is about ten minutes per slide. By mounting two slides one after the other and testing the two also one after the other, time could be saved. The time involved in taking the sample and in the preparation of the sliver is common to all the methods of study. The extra time necessary in the present work is that required for the mercerisation and dyeing of the sample. As this is a routine process it can be handed over to a skilled attender, if a large number of samples are to be examined. It follows, therefore, that apart from the time taken for other preliminary work, the actual time for the measurement is about 40 minutes (which can be reduced by practice) for one sample of two slides. This is small enough to enable the testing of a large number of samples. It should be mentioned, however, that the observer should be intelligent and should make the adjustments with great precision.

It can be concluded that the method developed in the present study is accurate, has a small experimental error and is quick enough for routine testing of a large number of samples.

Before closing it should be mentioned that it is easily possible to improve the accuracy of the instrument by having a differential arrangement with two photoelectric cells instead of one. By this means the difference in current, $I_1 - I_2$, is measured and by using a more sensitive galvanometer the deflection may be made large enough to be free from errors of measurement. It will involve some small alterations in the apparatus which can be easily made.

Summary

The fineness of the cotton fibre, as expressed by its diameter is an important character, especially in the case of the long staple cottons. A new method has been developed for determining quickly and accurately the mean diameter of a large number of fibres, which is applicable not only to cotton fibres but to other textile fibres, filaments, fine wires, etc.

In this method a uniform beam of light passing through an accurately made rectangular slit falls on a photoelectric cell producing a current I_1. A parallel bundle of opaque fibres, filaments, etc., with as little overlapping as possible, is interposed in the path of the beam perpendicular to the

length of the slit. The photoelectric current is reduced to I_2 depending upon the number, n, and the average diameter, d, of the fibres. If the intensity of the light source remains the same and if l is the length of the slit, it can be easily shown that

$$d = \frac{l}{n} \quad \frac{I_1 - I_2}{I_1}$$

The number, n, can be counted under a low-power microscope and the diameter can be calculated.

The apparatus, designed at the Technological Laboratory, consists of a hollow tube with an electric lamp, fed with a constant current, at one end. The light is rendered uniform by means of a condenser, and after passing through a water-cell for absorbing the heat rays, emerges through the slit and falls on a photoelectric cell of the Weston Photronic type. The current generated is measured on a galvanometer. The slit contains an arrangement to hold a slide for mounting the material. A special slide has been made by means of which fibres can be mounted quickly with very little overlapping. Transparent or semi-transparent fibres are rendered opaque by dyeing them with a suitable black dye, which does not affect their diameter.

Using the apparatus the average diameter of many textile fibres and other materials covering a wide range of values from 12μ to 117μ have been measured. Their diameters were also determined microscopically for purposes of comparison. In all cases the values obtained by the photoelectric method were not significantly different from those microscopically obtained. The method is found to give accurate results with a small experimental error and is quick enough for routine testing of a large number of samples.

Acknowledgements

Some preliminary work in connection with this study was done by late Mr. G. Rama Rao.

Reference

Ahmad, N. and Gulati, A. N. (1936). *J. Text. Inst.* XXVIII, T 109-111

Appendix

The fibre diameter, d_i, obtained from the values of the proelectric current is given by equation (3), that is

$$d_i = \frac{l}{n} \quad \frac{I_1 - I_2}{I_1} \qquad \text{.....................(4)}$$

If V_1 and V_2 are the respective photoelectric voltages, without and with the fibres respectively, and if d_v is the value of the diameter obtained from them,

then

$$d_v = \frac{l}{n} \quad \frac{V_1 - V_2}{V_1} \qquad \text{........................(5)}$$

If R_1 and R_2 are the respective resistances of the photoelectric cell, $V_1 = I_1 R_1$ and, $V_2 = I_2 R_2$

Therefore

$$d_v = \frac{l}{n} \quad \frac{I_1 R_1 - I_2 R_2}{I_1 R_1}$$

By dividing both the numerator and the denominator by R_1

$$d_v = \frac{l}{n} \quad \frac{I_1 - I_2 \dfrac{R_2}{R_1}}{I_1}$$

By adding and subtracting R_1

$$d_v = \frac{l}{n} \; \frac{I_1 - I_2 \left(\frac{R_1 + R_2 - R_1}{R_1} \right)}{I_1}$$

$$= \frac{l}{n} \; \frac{I_1 \; I_2 \left(\frac{R_2 - R_1}{R_1} \right)}{I_1}$$

$$= \frac{l}{n} \; \frac{I_1 - I_2}{I_1} - \frac{l}{n} \; \frac{I_2}{I_1} \; \frac{(R_2 - R_1)}{R_1}$$

Since from (4) the first term on the right hand side is equal to d_i

$$d_v = d_i - \frac{l}{n} \; \frac{I_2}{I_1} \; \frac{(R_2 - R_1)}{R_1} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Now R_2 is the resistance of the photoelectric cell with the lower illumination and, is, therefore, greater than R_1, the resistance with the higher illumination. Hence $R_2 - R_1$ is positive which makes $\frac{l}{n} \; \frac{I_2}{I_1} \; \frac{(R_2 - R_1)}{R_1}$ positive. This positive quantity is subtracted from d_i to give d and therefore the latter is smaller than the former as is experimentally found to be the case.

REVIEW

IMPERIAL BUREAU OF SOIL SCIENCE TECHNICAL COMMUNICATION NO. 43

Land Classification for Land-Use Planning BY G. V. JACKS

(Published by the Imperial Bureau of Soil Science, Harpenden, England, 19 6. Price 4*s.* 0*d.*)

LAND classification is of vital importance for land-use planning. The land and water resources of a country constitute the national heritage of the people living in it. An inventory has to be made of them by requisite surveys, they have to be preserved against loss and damage and utilized to the best advantage consistent with such conservation and handed down to posterity in an unimpaired, if not, improved state. The objective of a land-use plan must be clearly visualized and the rival demands on these resources have to be properly balanced, taking into consideration the trends of development of their use and local, regional and national needs. 'Land classification must form the starting point of land-use planning.' In the ultimate analysis the improvement of soil fertility and its maintenance at the optimum level must be the main foundation of plans of land use at least in so far as the production of plants of economic importance is concerned. With our population of 400 millions and annual increase at the rate of five millions and with the yield per acre of almost all our crops one of the lowest of that achieved in most countries, this question of conservation of land and of soil fertility obviously assumes national importance. There are various types of land classification in vogue, some of them based 'on considerations of economic factors, transport facilities and many others'. 'It is however usual to distinguish between physical, and the economic and social classification of land.' 'The physical or 'inherent' characteristics include the geology, climate and topography and are permanent in the sense that they cannot be profoundly altered by man. Geology, climate and topography are combined in the factor soil, which, though to some extent modifiable by man or other living organisms, is the main factor in a physical classification. A physical land classification is permanent, and once made can serve as the basis on which to superimpose an economic and social classification which will need to be modified with changes in economic and social conditions (e.g. market conditions and communications) as well as with the changes in the objective of the plan that may occur as the plan unfolds.' The economic standpoint is of course most relevant and 'important as it is essential to recognize that in planning optimal land use and

its success depends on economic soundness'. But 'the factors to be taken into account in economic and social classification will vary both as to their nature and the weight to be attached to each with the social objective of the plan'. 'In some instances, markets, in others communications, in others tradition and custom, in others political questions, may constitute the dominant factor, and there will always be many variable and fluctuating subsidiary factors.' 'Among the essential economic data are included uses of land, kind of ownership, land values, transportation facilities and markets for present and potential products: and among social data, distribution and kind of population, both rural and urban, and economic status (standard of living) of rural classes.' 'Such things as the passing of the physical frontier, the change of a country from debtor to creditor status, the loss of foreign markets, the approach to a stable population and the conflicts that arise in the national economy of a country between capital and labour' also require consideration. But 'by its very nature social-economic land classification must be labile and indefinite'. Land-use varies from time to time and is governed by a multiplicity of considerations. 'Classifications based on use-capabilities in order that it has to be of long-term validity' should also allow for probable developments in technique and science.

The approach that the U. S. A. Department of Agriculture, especially through its Soil Conservation surveys, has made towards the formulation and effectuation of land-use plans, is 'the best known and most successful'. It is based on a sample physical classification and 'social and economic factors do not enter into the land classification, but they do enter into the effectuation of the plan, and may necessitate modifications in the 'ideal' plan based on strict adherence to the physical land classification. The plans are made and carried out by the occupiers of the land themselves who can call upon outside experts to give advice and direction if required'. 'The prime objective of every soil conservation district plan is the same to save the soil from exhaustion and erosion.' 'In July 1945, 3,404,000 farms covering 734 million acres were included in the 1,328 soil-conservation districts which had been set up.' There are many other examples of land-use planning, e.g. that in use in Russia by some Russian collective farms (Kolkhozes). 'These plans are coordinated into a national plan by the central planning authority (Gosplan).' 'The kolkhoz is required to produce certain amounts of certain crops and is expected to adopt certain rotations and farming practices which have been shown to conserve soil fertility in the region concerned.' 'Under such circumstances a physicial land classification to suit the pre conceived plan which may be modified within limits to fit the land classes can readily be made. Social-economic factors enter to a variable but usually only to a minor extent.' There are other cases 'where the objective is less clear or less clearly related to definite uses of land, the land classification tends to be correspondingly vague': and 'an objective such as the common welfare, the public good, the improvement of the standard of living, or merely the optimal uses of land forms an insufficient basis for a land classification'. 'There is no such thing as a general land classification, but there is a common physical classification appropriate as a basis for land-use plans aiming to promote and perpetuate the public welfare and therefore requiring the maintenance of soil fertility. Superimposed on this basis is another social economic classification which is, in effect, part classification and part planning. It is often difficult to know where the process of land classification ends, and that of land planning begins.'

The extracts given above will convey an idea of recent trends in land classification for agricultural purposes. A very comprehensive account is given on the different aspects of land classification and the factors which govern it and of its objectives. The subject-matter has been discussed under the following heads:

Land classification and land-use planning

Types of land classification

The physical classification of land

Land inventories

The U. S. Soil Survey

Land types and soil types

Land types and genetic soil types
Land-use classes
Agricultural Regions
The estimation of population capacity
Population and land quality
The use of natural vegetation as an indicator of land quality
Plant indicators of forest-site quality
Grassland indicators
System of land classification :
1. Michigan
2. U. S. Soil Conservation Service
3. Tennessee Valley Authority
4. New York State
5. Western Canada :
   Saskatchewan
   Alberta
6. Ontario
7. New Zealand
8. Great Britain
9. Prussia
10. Land classification for irrigation purposes
The Estimation of Productivity :
   Productivity ratings
   The Storie index
   Canadian rating systems :
      Saskatchewan
      Alberta
   Ranking Coefficients
   German soil ratings—Bodenbonitierung

This publication is most welcome and especially opportune at this moment. The information on land classification is scattered in publications in different languages and Mr Jacks has done a great service to all interested in the subject by collating them together and elucidating them with his comments. The approach has, however, been mainly factual.

PLANT QUARANTINE NOTIFICATIONS

Notice No. 1 of 1946. Notifications of Foreign Plant Quarantine Restrictions received in the Bureau of Plant Protection and Quarantines, Department of Agriculture, Government of India, New Delhi, during the period January to June 1946.

The following Plant Quarantine Notifications have been received in the Bureau. Those interested are advised to apply for details to the Plant Protection Adviser to the Government of India.

1. Gypsy moth and Brown-tail moth Quarantine : Domestic Quarantine Notice No. 45, dated 10th October, 1945 : U.S.A. Deptt. of Agriculture B.E.P.Q. No. 72.	Restrictions to prevent spread of these moths in the United States.

2. Mexican Fruitfly Quarantine: Domestic Quarantine Notice No. 64, dated the 26th Nov. 1945: U. S. Department of Agriculture B. E. P. Q. No. 64.	Restrictions to prevent the spread of the Mexican fruitfly (*Anastrepha ludens*) outside the state of Texas.
3. White-Fringed Beetle Quarantine: Domestic Quarantine Notice No. 72, dated the 12th December 1945: U. S. Department of Agriculture B. E. P. Q. No. 72.	Restrictions to prevent spread of the White-fringed Beetle (*Pantomorus* spp.) in the United States.
4. Plant-Quarantine Import Restrictions of the Republic of Cuba: B. E. P. Q. No. 509—Supplement No. 2, dated 8th February 1946: issued by U. S. Department of Agriculture.	Referring to amendations of regulations governing the importation of seed-potatoes into Cuba.
5. Plant-Quarantine Import Restrictions of the Republic of Bolivia: B. E .P. Q. No. 484 (Revised), dated 8th February, 1946: issued by the U. S. Department of Agriculture.	Contains a digest of the plant-quarantine import restrictions of the Republic of Bolivia for the information of importers.
6. Plant-Quarantine Import Restrictions of Jamaica, British West Indies; B. E. P. Q. No. 547, dated the 21st March, 1946 (superseding B. P. Q.—355—Revised): issued by the U. S. Department of Agriculture.	Contains a revised summary of the plant-quarantine restrictions of Jamaica for the information of nurserymen, etc.
7. Plant-Quarantine Import Restrictions of the Kingdom of Egypt: B. E. P. Q. No. 375—2nd Revision, dated the 19th April, 1946: issued by the U. S. Department of Agriculture.	A Revision of the plant-quarantine import restrictions of the Kingdom of Egypt.
8. Plant-Quarantine Import Restrictions of the Republic of Mexico: B. E. P. Q. No. 411—Supplement No. 4, dated 25th April, 1946: issued by the U. S. Department of Agriculture.	Refers to certain amendments in the restrictions of the import of corn into Mexico from the United States on account of the European Corn Borer (*Pyrasta nubilalis*).
9. Plant-Quarantine Restrictions of the Ministry of Agriculture in Iran: Communicated by Consul General for Iran in India, dated 3rd June, 1946.	All plants and vegetables imported into Iran should be accompanied by certificates of freedom from various pests and diseases in list attached with the letter.

MGIPC—M—III-1-1—12-4-48—600.

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The Editorial Board, in its work of examining papers received for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

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Communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

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Articles intended for THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE should be accompanied by short popular abstracts of about 300 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References to literature, arranged alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state 'Original not seen'.

Sources of information should be specifically acknowledged.

As the format of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{8}$ in. × $9\frac{5}{8}$ in. cut), no text-figure, when printed, should exceed $4\frac{1}{2}$ in. × 5 in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space available for figures being $5\frac{3}{4}$ in. × 8 in. exclusive of that for letter press printing.

Copies of detailed instructions can be had from the Secretary, Indian Council of Agricultural Research, New Delhi.